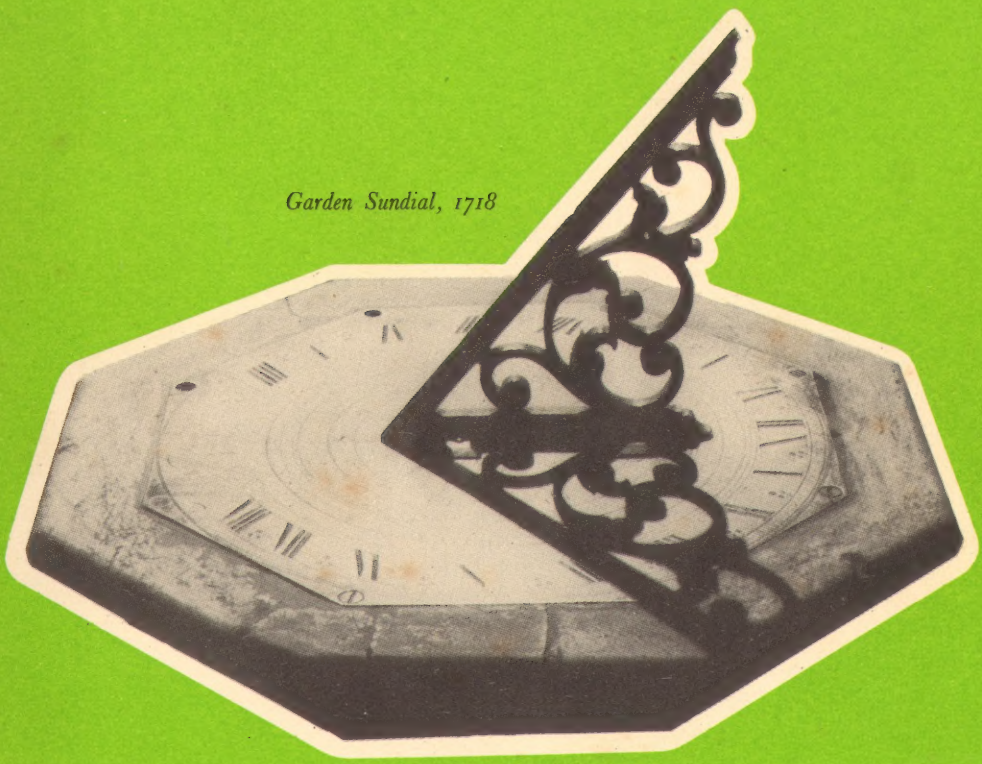
Time Measurement



Garden Sundial, 1718

PART II

DESCRIPTIVE CATALOGUE

SCIENCE MUSEUM

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MINISTRY OF EDUCATION · SCIENCE MUSEUM

HANDBOOK OF THE COLLECTION ILLUSTRATING TIME MEASUREMENT

By

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Part II

DESCRIPTIVE CATALOGUE

Third Edition

LONDON : HER MAJESTY'S STATIONERY OFFICE

1955

I-23911

First published – *April 1937*
Second Edition – *June 1950*
Third Edition – *1955*

PREFACE

THE FORMATION of a Museum of Science was first proposed by the Prince Consort after the Great Exhibition in 1851, and in 1857 collections illustrating foods, animal products, examples of structures and building materials, and educational apparatus were brought together and placed on exhibition in South Kensington. The collections of scientific instruments and apparatus were first formed in 1874, but it was only after 1876 that they became of importance. The Special Loan Collection of Scientific Apparatus which was exhibited in that year in the Museum brought together examples of all kinds from various countries, and a large number of these were acquired for the Museum. Subsequently many additions were made, including in 1884 the collection of machinery formed by the Commissioners of Patents, in 1900 the Maudslay Collection of machine tools and marine engine models, and in 1903 the Bennet Woodcroft Collection of engine models and portraits.

Until 1899 the Art Collections and the Science and Engineering Collections together formed the South Kensington Museum, but in that year the name was changed to the Victoria and Albert Museum, which included both Collections until 1909, when it was restricted to the Art Collections; those relating to Science and Technical Industry have since then formed the Science Museum.

The aim of the Science Museum, with its Collections and Science Library, is to aid in the study of scientific and technical development, and to illustrate the applications of physical science to technical industry. This is effected by the informative display of objects, diagrams and photographs—so arranged as to illustrate in each Section the development which has taken place from past to modern practice.

Many of the exhibits in the Time Measurement Section are shown in continuous operation, while others are so arranged that they can be operated by visitors or demonstrated to them. The modes of action of several of the more delicate watch mechanisms are illustrated by large-scale models.

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INTRODUCTION

PART I of the Time Measurement Handbook consists of a brief review of the history of Time Measurement, together with notes on the principles employed in measuring time. The present volume, Part II, contains detailed descriptions of the objects exhibited in the Time Measurement Section of the Science Museum. These descriptions contain the substance of the descriptive labels exhibited with the various objects, but are not necessarily identical with the labels. Additional information concerning certain exhibits may be obtained by consulting the detailed references to books, journals or patent specifications given at the end of the appropriate descriptive texts. Many of these works may be seen in the reading room of the Science Library, the British Museum, or the Patent Office Library, whilst the works in the Science Library may be obtained on loan through the medium of an approved institution or industrial organisation.

The Collection is classified into a number of large groups which are further divided into sub-groups: within each sub-group the exhibits are arranged as far as possible in chronological order. At the foot of the description of each object the identification number of the object in the Museum's Inventory is given.

A number of objects in the Collection have been photographed, and in these cases the identification number of the negative or negatives is also given at the foot of the Catalogue description of the object. Prints and lantern slides from these negatives may be purchased from the Museum; in addition, lantern slides may be borrowed from the Loan Collection. For particulars of the conditions of loan and for the price of prints, etc., application should be made at the bookstall near the main entrance of the Museum, or by letter addressed "The Director and Secretary, the Science Museum, South Kensington, London, S.W.7."

The numbered Catalogue entries include all objects on exhibition at the time of going to press (January, 1955). Owing to shortage of exhibition space not all the exhibits in the Collection can be shown, and the supplementary list at the end of this Catalogue contains titles and in some cases brief descriptions of the more important objects at present in store. Most of these may be seen on written application to the address given above, provided that sufficient notice is given.

I. PRIMITIVE AND OTHER NON-MECHANICAL DEVICES

THE earliest time-measuring devices which have survived to the present day are the primitive sundials or shadow-clocks and the water-clocks of ancient Egypt. These types of instrument were developed and improved by the Greeks and were in use throughout the periods of the Greek and Roman Empires; together with the sand-glass they were still the only timekeepers generally employed throughout the Dark Ages and the early Middle Ages.

The Time Measurement Collection includes casts or copies of ancient Egyptian shadow-clocks and water-clocks, together with examples of other relatively primitive non-mechanical time-measuring devices.

A collection of over 70 sand-glasses was presented to the Museum in 1952 by the Right Rev. Abbot Horne of Downside Abbey: this is referred to as "The Abbot Horne Collection".

The evolution of the sand-glass was in three main stages.

In the earliest type the two bulbs were separately blown; a metal plate with a small orifice was placed between the two bulbs and the whole joined together with wax or plaster to form a single unit.

After about 1750 glasses blown in one piece appeared and soon became standard, the remaining opening in one bulb being sealed with a cork.

In the third type, introduced about 1800, this opening was sealed by the glass-blower, so that the sand-glass became airtight.

The three types are referred to in the Catalogue as A, B and C respectively.

1. SHADOW CLOCK (10TH to 8TH CENTURY B.C.).

This is a reproduction of an early Egyptian shadow-clock. The original, in the Neues Museum at Berlin, was made of a green schist and dated from the 10th to the 8th century B.C. The instrument appears to be incomplete and requires a cross-piece as shown in the adjacent sketch.

In use the instrument would be placed with the base in an east and west direction, and the shadow of the edge of the cross-piece would fall upon the base, upon which a scale of "hours" is marked. The period from sunrise to noon would thus be divided into six roughly equal parts; at noon the instrument would be reversed, and the period from noon until sunset would be roughly divided into six parts again. The "hour" marks give the names of the hours of the day from the "hour of rising" at the far end to the hour of "high standing" (noon) at the vertical face.

[See "Die Geschichte der Zeitmessung und der Uhren," edited by E. von Bassermann-Jordan, Band I, Lieferung B, "Altägyptische Zeitmessung," by Dr. L. Borchardt.]

Inv. 1923–584, Photo 1946.

2. "MERKHET", AN ANCIENT EGYPTIAN INSTRUMENT FOR DETERMINING TIME (see Plate I). Presented by Dr. Howard Carter.

This holder for a plumb-line, called "Merkhet" by the Egyptians, and "horologos" by the Greeks, was used from very early historical times in Egypt to lay out axes of buildings and for observing the transit of selected stars across the meridian to determine the hour of the night. (See exhibit in Gallery 64, Astronomy.)

This example dates from about 600 B.C. and was the property of one Bes, the son of Khensartais, as the inscription states; he was an astronomer priest of the God Horus of Edfu in Upper Egypt.

It is of bronze, inlaid with a gold-silver alloy, electrum.

Inv. 1929–585, Photos 5496, 5502.

3. SHADOW CLOCK (see Plate I). Presented by W. M. Hayes, Esq.

This is an example from Qus of a type of primitive time-measuring instrument which is still used in Upper Egypt. It is similar in principle to the ancient Egyptian shadow clock of the 10th to 8th century B.C.

Mounted on the middle of a wooden board, which is placed in an east and west direction, there are two short vertical sticks which are joined at the top by a transverse horizontal piece and resemble a miniature goal. The position of the shadow cast by the transverse piece is utilized to indicate the passage of intervals of time, the board being graduated for this purpose in the example shown by tin tacks.

An initial mark is made after sunrise and calibration of the successive periods is made by comparison with a water clock, known as a "qadus," which consists of an earthenware pot with a small hole at the bottom. The pot is filled to the brim with water and the time required to empty it is taken as a unit. The periods indicated on the board are not hours of time and may correspond to one or more units depending upon the purpose for which the instrument is required. Such purposes are to indicate the duration of the tasks of labourers or oxen and, in connection with irrigation, to measure the flow of water to different plots of land.

Various modifications of the instrument are employed; in some a piece of twine replaces the horizontal piece, and a slab of clay is used instead of the wooden board. The "goal posts" may also be mounted directly on a levelled surface of ground.

Inv. 1926–992, Photo 3209.

4. CAST OF EARLY EGYPTIAN WATER-CLOCK. Presented by the Egyptian Government,

The original of this cast was found at Karnak Temple, Upper Egypt, in 1904 and dates from the reign of King Amenhotep III, 1415–1380 B.C.; it is now in Cairo Museum. It is made of alabaster, and was probably used for indicating the passage of the hours of the night.

In use, the vessel was filled with water, which leaked out slowly from a small hole near the bottom, and the time was indicated by the level of the water within. With a vessel of this shape the water-level falls fairly uniformly, for the more rapid flow when nearly full is compensated by the greater cross-section of the vessel near its top, a greater outflow of water then being required to produce a given decrease of level.

At this epoch it was customary to divide the periods of daylight and of darkness each into 12 "temporal" hours, so that the length of an hour of the day differed from that of an hour of the night (except at the equinoxes) and both varied according to the season of the year. A separate scale of time was therefore required for each month of the year, and there are accordingly twelve series of dots marked on the inner surface of the vessel, the name of the month to which each scale refers being marked on the rim of the vessel above the scale in question.

[See "Die Geschichte der Zeitmessung und der Uhren," edited by E. von Bassermann-Jordan, Band I, Lieferung B, "Altägyptische Zeitmessung," by Dr. L. Borchardt.]

Inv. 1923–48, Photos 3270, 3266, 13/39 to 18/39.

5. PHOTOGRAPHS OF EARLY EGYPTIAN WATER-CLOCK. From Karnak Temple. Presented by the Egyptian Government.

These show the original water-clock of which a cast is exhibited adjacently (Catalogue No. 4). Inv. 1923–115.

6. CAST OF EARLY EGYPTIAN WATER-CLOCK. Presented by the Egyptian Government.

The original of this cast was found at Edfu, Upper Egypt, in 1901, and probably dates from the first or second century of the Christian era, when Egypt was under Roman rule. The vessel, which is now in Cairo Museum, is made of white limestone, and was used for dividing up the periods of daylight or of darkness each into twelve hours, according to the system of time-reckoning in use at this epoch (see Catalogue No. 4).

In use, water would be allowed to trickle into the vessel at a uniform rate, so that the level of the water within would rise at a uniform rate: the time was indicated by the level of the water inside the vessel, and may also have been shown on an external scale, now lost, by means of a pointer mounted on a float and projecting above the top of the vessel.

As in the adjacent clock, separate time-scales are provided on the interior surface of the vessel for each month of the year, in order to allow for the varying lengths of the "temporal" hours at different seasons. Inv. 1923–49, Photo 2349.

7. "SINKING BOWL" WATER-CLOCK (Copy).

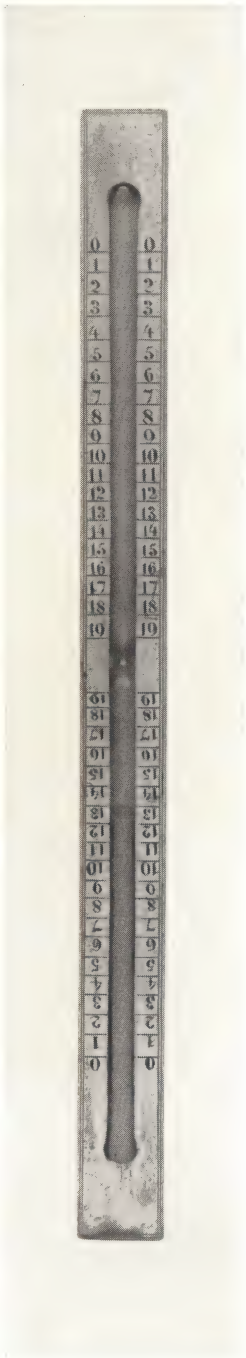
The original bronze bowl of which this is a copy was found in a bog in County Antrim, Northern Ireland, and is now in the British Museum. It is of the type which was employed by the Ancient Britons, probably under the influence of the Druids, for measuring intervals of time.

The bowl has a small hole in the bottom, and in use it was placed on the surface of water, which slowly leaked into it until, after a definite interval of time, the bowl sank. The interval was used as a unit of time; in the case of the present bowl it is approximately one hour.

PLATE I

Astronomical Instrument, "Merkhet," from Ancient Egypt, about 600 B.C. (Cat. No. 2).

Primitive (Modern) Shadow-Clock from Egypt (Cat. No. 3).



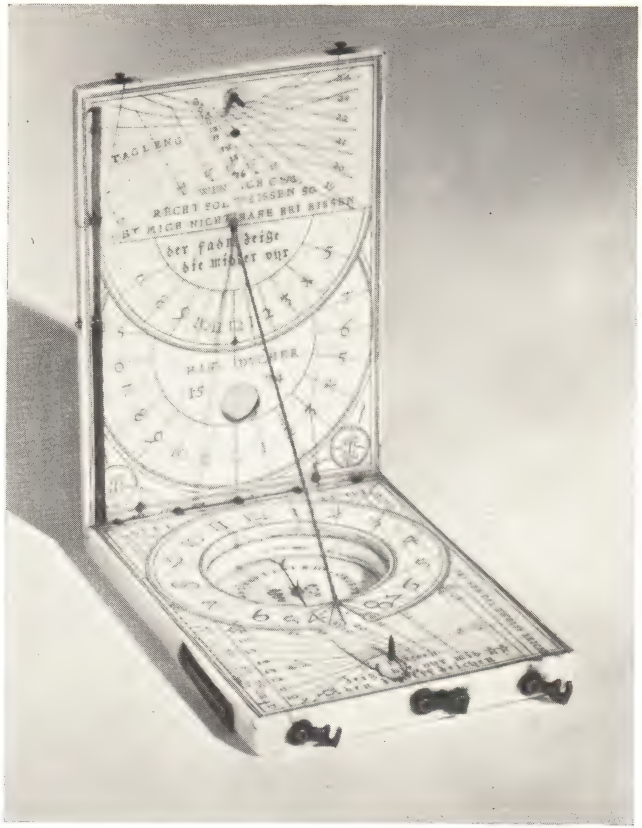
Sand-Glass graduated in Minutes (Cat. No. 15).

18th-Century Lamp Timekeeper (Cat. No. 10).

Garden Sundial, 1718 (Cat. No. 43).

Florentine Cubical Sundial of about 1560, showing Italian hours (Cat. No. 45).

PLATE III



Ivory Tablet Sundial by Hans Ducher, 1574 (Cat. No. 70).

Pocket Ring Sundial, 1736 (Cat. No. 89).

PLATE IV

Bowls of this type have been found in many places in the British Isles, also in India and Ceylon. It is not known whether their use originated independently in such widely separated parts of the world or whether the custom was transmitted from one part to the other.

[See Proceedings of the Society of Antiquaries, vol. 21, p. 319 (1907) and vol. 27, p. 76 (1916).] Inv. 1931–834, Photo 9/46.

8. ALGERIAN WATER CLOCK. Lent by Captain M. W. Hilton-Simpson.

This shows a primitive form of water clock consisting of a floating bowl, into which the water leaks through a small hole at the bottom and causes the bowl to sink after a certain interval of time, in this case about 15 minutes.

Appliances of this type are used in Algeria for timing the periods for which the various landowners are entitled to the supply of water for irrigation purposes. Inv. 1924–314.

9. WATER CLOCK.

This form of water clock or clepsydra indicates hours of equal lengths and was introduced about the middle of the 17th century. The example is of English make and of about 1700.

It consists of a closed metal cylinder or drum suspended from a stand by means of two cords attached to a horizontal axle, which projects from the flat ends of the drum. The drum contains a small quantity of water and a number of partitions passing from its circumference tangentially to an imaginary circle of about one-third the diameter of the drum. When the drum is wound up, the cords are wrapped round and round the axle and the water falls over the inner and open edges of the partitions into the lowest portion of the drum. The weight of the drum then tends to make it descend, while the weight of the water in the bottom part opposes this motion which would, in the first place, involve raising this water to a higher level. As, however, the partitions are perforated, water can pass gradually from one chamber to another, and the drum descends slowly, the position of the axle indicating the time on a vertical scale. Inv. 1894–131, Photos 1157, 3384.

10. LAMP TIMEKEEPER (see Plate II).

This is an 18th century oil clock from North Germany. It consists of a pewter stand and lamp, the reservoir of which is of glass and graduated from 8 p.m. to 7 a.m. to indicate the hours of the night by the quantity of unburnt oil left in the reservoir.

No approach to accuracy could have been obtained with this lamp, which has an egg-shaped reservoir and an equally divided scale over its full length. Some lamps of this type, however, have reservoirs which are cylindrical except for the ends.

Inv. 1926–233, Photo 7292.

11. "ATMOSPHERIC" TIMEPIECE.

In this 19th century timepiece a pellet of mercury falls slowly down a uniform glass tube each end of which contains a porous plug. The rate of fall of the pellet is governed by the viscous flow of the air through the two plugs. The whole is sealed within an outer glass tube, and the time is shown by the position of the pellet relative to one of two wooden scales.

The pellet falls through the full length of the tube between the plugs in 20 hours and the tube can then be inverted. Inv. 1953–365.

12. SIX-STAGE SAND-GLASS.

This sand-glass probably dates from the early 17th century and is of the earlier type in which the main bulb and the six-stage bulb are blown separately and then pressed together at the necks.

The $\frac{1}{2}$ hour period of the glass is sub-divided by the six smaller bulbs, each of which empties or fills in 5 minutes.

Inversion of the glass was made simple by fitting it to a wall pivot by means of the hole in the back of the wooden case.

When acquired, the necks of the two bulbs were without binding and badly damaged, and permitted the obvious loss of sand. The original diaphragm is missing and has, at some time, been replaced by a small glass tube very crudely inserted in the main bulb. The present joint of putty was added in the Museum. Type A. Inv. 1954–127.

13. SET OF FOUR SAND-GLASSES.

This set of four sand-glasses probably dates from the 17th century. The glasses are mounted in a brass frame pivoted to a fitting which can be hung on a wall, so that they can be inverted as required. The glasses measure intervals of time of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 hour respectively, and are of the type which was formerly used by preachers for timing their sermons. Type A. Inv. 1942–23, Photo 55/50.

14. SET OF FOUR SAND-GLASSES.

This set of sand-glasses resembles the adjacent one (Catalogue No. 13), but is mounted in a wooden frame. There is no pivoting arrangement in this case, and the frame is intended to stand either side up upon a flat table. Type A. Inv. 1942–22, Photo 56/50.

15. SAND-GLASS (see Plate II). Presented by J. N. Brice, Esq.

This instrument is graduated in minutes from 1 to 19.

Although the action of a sand-glass has some resemblance to that of a water clock there is a fundamental difference in that the rate of passage of the sand is independent of the height of the column above the orifice. The angle of the double cone connecting the two chambers at the orifice is made equal to the angle of repose of the sand. Type C.
Inv. 1911–209, Photo 5703.

16. SET OF FOUR SAND-GLASSES.

This set of glasses in an ornate mount of ebony and ivory is probably Italian and two of the glasses bear the date 1720.

The glasses are marked $\frac{1}{4}$, 2/4, $\frac{3}{4}$ and 4/4 respectively; the time intervals are also indicated by the appropriate number of ivory studs set above and below each glass on the enclosing panels, each stud representing $\frac{1}{4}$ hour.

The filling is of fine emery powder instead of sand, the construction being that of the early type in which two separate bulbs are joined at the necks. Type A. Inv. 1953–414.

17. FOUR-HOUR SAND-GLASS. Bequeathed by F. C. Ihlee, Esq.

It has long been customary in ships to divide up the 24-hour day-and-night period into intervals of four hours, termed "watches," half the ship's company being on duty during each watch. This large sand-glass, which probably dates from the 18th century, is of the type which was used in ships for marking the lengths of the watches. The glass would be hung up by its ropes and inverted at the end of each watch.

The four-hour period from 4 p.m. to 8 p.m. was divided into two watches, each of two hours' duration, and the passage of every half-hour was signified by an appropriate number of strokes on the ship's bell. An additional 30-minute sand-glass was supplied for timing these shorter intervals. Type A. Inv. 1938–641, Photo 29/47.

18. PORTABLE SAND-GLASS IN BRASS CASE. Presented by Dr. W. L. Hildburgh, F.S.A.

This sand-glass probably dates from the 17th century and is of the earlier type in which two separate bulbs are joined together at the necks. Type A. Inv. 1937–186.

19. SAND-GLASS. Presented by The Admiralty.

This 19th century glass is of the type used in ships in connection with the hand log for obtaining the speed of the vessel. Its sand passes from the upper to the lower chamber in a period of 14 seconds, and the instrument is inverted when it is again to be used. Type C. Inv. 1920–360, Photo 1590.

FROM THE ABBOT HORNE COLLECTION

20. SAND-GLASS.

A sandglass of the earliest form dismantled to show the two separate bulbs and the metal diaphragm. Type A. Inv. 1953–304.

21. POCKET SAND-GLASS.

Pocket sandglass in a double leather case which is closed by twisting. Fine emery powder is used instead of sand. Fifteen minutes. Type A. Inv. 1953–299.

22. TEA-TASTER'S SAND-GLASS.

Tea-taster's sandglass, used for timing the infusion of tea. Each of the four small bulbs fills or empties in one minute. Type A. Inv. 1953–300.

23. HALF-HOUR GLASS.

A typical example of a $\frac{1}{2}$-hour glass in an ebony mount with turned columns and ivory feet. Type A. Inv. 1953–302.

24. EARLY PORTABLE SAND-GLASS.

Early portable sandglass in a double brass case. Running time 12$\frac{1}{2}$ minutes. Type A.
Inv. 1953–303.

25. DIVINE OFFICE GLASS.

Divine office glass in a double brass case. Running time 9¼ minutes. Type A. Inv. 1953–301.

26. QUARTER- AND HALF-HOUR DOUBLE GLASS.

Early quarter- and half-hour double glass. The joints are wax or plaster bound with leather. Type A. Inv. 1953–312.

27. ONE-HOUR SERMON GLASS.

One-hour sermon glass in a plain wooden mount. Beneath the base of each bulb are latin inscriptions around, at one end, the coloured picture of a chalice and at the other, the initials J.H.S. Type A. Inv. 1953–403.

28. UNMOUNTED SAND-GLASS.

An unmounted sandglass of the second form showing the corked filling hole in one bulb. Type B. Inv. 1953–308.

29. PORTABLE SAND-GLASS.

Portable sandglass in silver mount, hall-marked 1799. Fine emery is used instead of sand. Running time 4 minutes. Type B. Inv. 1953–307.

30. 14-SECOND LOG-GLASS.

14-second log-glass in a crude wooden mount. Used in conjunction with a hand-log to estimate a ship's speed. Type B. Inv. 1953–404.

31. 14-SECOND LOG-GLASS.

14-second log-glass in a brass case. The filling is of fine emery powder. Type B. Inv. 1953–405.

32. HOUR-GLASS.

An hour-glass in a wooden mount with turned columns. Type B. Inv. 1953–406.

33. HALF-HOUR GLASS.

It has a ground waist with a copper diaphragm and is sealed with a cloth-covered cork. Type B. Inv. 1953–407.

34. UNMOUNTED SAND-GLASS.

An unmounted sandglass of the latest form showing the bulbs completely sealed. Type C. Inv. 1953–311.

35. ALARM SAND-GLASS.

The glass is mounted in a wire framework in such a manner that, at a preset time up to 4½ minutes, it causes the bell to be struck. Type C. Inv. 1953–309.

36. "EGG TIMER."

"Egg timer," mounted in a swivel iron frame on a brass base. 2½ minutes. Type C. Inv. 1953–310.

37. HALF- AND ONE-HOUR DOUBLE GLASS.

The one-hour glass is of type B, the other, which is probably a replacement, is of type C. Inv. 1953–313.

38. QUARTER-MINUTE PULSE GLASS.

Early quarter-minute pulse glass used by doctors and nurses when taking a patient's pulse rate. Type C. Inv. 1953–314.

39. QUARTER-MINUTE PULSE GLASS.

Modern (1948) quarter-minute pulse glass. Type C. Inv. 1953–315.

40. HALF-HOUR GLASS.

Half-hour glass in polished wooden mount. Type C. Inv. 1953–408.

II. SUNDIALS, NOCTURNALS AND PERPETUAL CALENDARS

FIXED SUNDIALS indicate the time by means of the sun's position or "hour-angle" in the heavens; they are designed for use in the latitude in which they are set up, and would not show accurate time if set up in any other latitude.

Portable sundials can be divided into two main classes:

(1) *Compass* dials, which embody or require a compass for setting in the correct position and depend, like fixed dials, upon the sun's *position* in the heavens.

(2) *Altitude* dials, depending upon the sun's height or "*altitude*" above the horizon.

Compass dials almost invariably employ a gnomon set parallel to the earth's axis, since with this construction the same scale of hours serves for all seasons of the year. All altitude dials embody a scale of dates, since the time cannot be found from the sun's altitude alone unless the date is known.

Portable dials of both classes may be designed for use in one latitude only, or may be "universal", *i.e.*, adjustable for use in any latitude within a wide range.

Some portable sundials are small enough to be carried in the pocket, and these pocket dials are separately grouped in the Museum Collection.

FIXED SUNDIALS

41. PLASTER CAST OF A ROMAN SUNDIAL.

The original dial from which this cast was made is in the British Museum, and was found at Civita Lavinia, near Rome. It is of limestone, and is of the type known as the "hemicycle," said to have been invented by Berosus, the Chaldean astronomer, about 300 B.C.

In Greek and Roman times the function of the sundial was to divide the period from sunrise to sunset into twelve equal parts, and this the hemicycle does. The gnomon, now missing, consisted of a style projecting horizontally from the centre of the curved uppermost edge of the dial. The shadow of the tip of this style would describe each day a curve on the hollowed-out portion of the dial, crossing in succession the eleven engraved hour-lines. At the summer solstice, the shadow would follow the lowermost curve, at the winter solstice the uppermost curve, and at the equinoxes the intermediate curve.

Measurements show that the dial is designed fairly accurately to indicate time on the Roman system at the latitude of Rome, 42° N. Inv. 1948–135, Photo 59/50.

42. EARLY ENGLISH SUNDIAL.

This is a plaster cast of the stone sundial on the south face of Bewcastle Cross, Cumberland, and has been prepared from a similar cast in the Royal Scottish Museum, Edinburgh. The dial markings are cut on the actual stone of the cross, which also bears various inscriptions. One of these can be transcribed as "First year of the king of this realm Ecgfrith" and this inscription enables the cross to be dated at approximately 670 A.D.

At this period it was customary in England to divide the day from sunrise to sunset into four "tides," and corresponding to this division the dial possesses four main hour-lines—a horizontal one for sunrise and sunset, a vertical line for midday and two intermediate lines, which are drawn at 45°. Each of these main lines is marked with a cross-stroke, and there are in addition two intermediate lines between each pair of the main lines. These correspond to a division of the day into twelve parts, but it is possible that they were cut at a later date.

The gnomon is missing, but it is conjectured that it stood out horizontally. Such a gnomon would correctly indicate sunrise, sunset and midday, but its shadow, falling upon the equally-spaced hour-lines, would not divide the daylight hours into equal parts, the morning and evening "hours" so obtained being longer than the ones nearer midday; the

difference in length would also vary according to the season of the year. It is evident therefore that dials of this type were intended to give only a rough sub-division of the day, but this may have been all that was required at the period in question.

Inv. 1935–11, Photo 7712.

43. GARDEN SUNDIAL (see Plate III). Made by William Deane, London, 1718.

This is a typical horizontal sundial for use in gardens. It has an ornamental gnomon for a latitude of 51·5° and is divided to read minutes.

Inside the hour circle there is a graduated circle of dates with indication of the corresponding "equation of time," thus facilitating a conversion from the true solar time shown by the dial to mean solar time. Inv. 1920–85, Photo 8156.

44. HORIZONTAL SUNDIAL.

This instrument, of French make, is dated 1782, and its gnomon is fixed on a small cannon, which may be discharged at noon.

A lens carried on an adjustable arm focuses an image of the sun on the touch-hole of the piece. Inv. 1880–52.

CUBICAL DIALS

45. CUBICAL SUNDIAL (see Plate III).

This Florentine instrument was made about 1560 and is of wood painted in distemper with arabesques. The cube has dials with short styles on five of its faces.

The dials on the north and south faces indicate the time in old Italian hours, in which system the day was divided into 24 equal hours beginning and ending at sunset, while the top dial shows Babylonian hours in which the day similarly consisted of 24 hours beginning at sunrise.

The east and west dials indicate the time in the ancient Jewish system in which the periods from sunrise to sunset and sunset to sunrise were each divided into twelve hours the length of which depended upon the time of year and also upon whether the hours of day or of night were being recorded.

The instrument shown is for latitude 46°. It was formerly in the Pitti Palace, Florence.

Inv. 1883–128, Photo 19,290.

46. CUBICAL SUNDIAL. Made by D. Beringer. Presented by T. H. Court, Esq.

This 18th-century instrument has five gnomons giving readings on different faces of a cube.

It is designed to be level at a latitude of 50°, but it is mounted on a jointed stand and could be set for other latitudes by means of a graduated scale and a plummet (now missing). This instrument forms an interesting illustration of the manner in which sundials can be drawn on any plane provided the edge of the gnomon is parallel to the earth's axis. A compass is provided for setting the instrument in position. Inv. 1917–96.

PORTABLE COMPASS SUNDIAL

47. ITALIAN CUP SUNDIAL, 1580.

The time is shown by the position of the shadow of the tip of the vertical style.

There are two sets of hour-lines in the cup: the full, curved lines numbered 9 to 24 for reading the time in "Italian" hours, and the broken lines numbered from 6 to 12 and 1 to 5 for reading in hours a.m. and p.m.

The sundial is inscribed: Hyeronimus Vulpariæ Florentinus Faciebat A.D. MDLXXX.

Inv. 1952–233, Photo 475/53.

PORTABLE UNIVERSAL COMPASS DIALS

48. PORTABLE UNIVERSAL SUNDIAL. Made by Christopher Köhler, Dresden, 1677.

On the base is mounted a folding equatorial hour circle which has a pin gnomon and can be adjusted for the latitude required by means of a graduated quadrant.

The hour circle is double, an inner one showing ordinary hours being surrounded by an outer one which can be rotated and adjusted in position to show Italian hours.

The instrument can be folded flat, and the cover has lunar circles outside and a perpetual calendar on the interior. Inv. 1880–30.

49. UNIVERSAL RING SUNDIAL.

This 18th-century instrument, of German make, has a pin gnomon, the shadow of which, on an equatorial hour circle, indicates the time. Beneath the case is inscribed "No. 116 Se 61812. Toda M. Adakymoe."

A compass is provided, as well as a plummet for adjusting the instrument to various latitudes. A gap in the ring allows it to be used about noon at the equinoxes, when the shadow of the front edge of the hour circle would otherwise prevent readings.

Inv. 1880–46.

50. UNIVERSAL SUNDIAL.

In this late 17th-century German sundial an arm parallel to the equator carries the equivalent of a pair of parallel plates, the edges of which are parallel to the polar axis.

The time is indicated by the position of the shadow cast by one or other of the edges of the upper plate, upon the upper surfaces of the lower plate and upon the vertical surfaces between the two plates.

The instrument is made of copper, and the arm, which is hinged, can be adjusted for different latitudes. For convenience of construction the plates are not made continuous.

Inv. 1880–38.

51. UNIVERSAL RING SUNDIAL.

This is an 18th-century sundial with an equatorial ring, which is hinged to the base plate and is so adjusted for latitude.

The time is shown by the shadow of the edge of a plate mounted in the ring. The various parts of the instrument can be folded flat. Inv. 1892–17.

52. PORTABLE UNIVERSAL COMPASS SUNDIAL. Presented by J. Bentley Bennett, Esq.

This dial is by Dollond, the well-known 18th-century London maker. It consists of an ordinary horizontal dial designed for a latitude of 60°, the whole dial with its gnomon being hinged at one end so that it can be tilted up out of the horizontal plane and so used over a wide range of latitudes from 60° down to zero. An arc graduated in degrees of latitude is provided so that the instrument can be readily set for use in any given latitude.

The instrument embodies a compass so that it can be set in the correct orientation and is provided with three levelling screws and two spirit-levels arranged at right-angles to one another, so that it may be accurately levelled. For convenience in carrying it is arranged to fold up into a small space. Inv. 1937–859, Photo 672/37.

COLUMN DIALS

53. COLUMN SUNDIAL.

This is of gilt bronze and was made at Augsburg, Germany, about 1550. It consists of a vertical cylinder mounted upon a cubical box and the time is indicated upon the sides of the box as well as on the cylindrical surface.

On the top of the cylinder there is a horizontal gnomon mounted on a loose cap which is adjusted by rotation for the sun's position in the zodiac. The instrument is then turned until the shadow of the gnomon is vertical, and the tip of the shadow will indicate the time by reference to a series of inclined hour lines on the cylinder. As, however, the measurement depends upon the sun's altitude, which is the same at equal intervals of time before noon and after noon, it is necessary to know whether the sun is east or west of the meridian, and a magnetic compass consequently forms part of this instrument, though it is not usually fitted to column dials.

The time is indicated on the faces of the cubical box by the positions of the tips of the shadows of short horizontal styles.

This instrument is for a latitude of 48°, and the cap, gnomon, and styles are not the originals. Representations of men taking various observations are engraved on the sides of the box. Inv. 1883–124.

54. COLUMN SUNDIAL.

This 17th-century instrument is similar in principle to the adjacent 16th-century column sundial (Catalogue No. 53), but the column is surmounted by a figure of a dragon, the tail of which serves as the gnomon. It is designed for use in a latitude of 45°.

Inv. 1883–132, Photo 8384.

55. PORTABLE WOODEN COLUMN SUNDIALS.

A column or cylinder sundial enables the time to be found from the sun's altitude. The cap of the dial, carrying the gnomon, is rotated by hand until the gnomon is vertically above the date on which the dial is being used. The dial is then suspended by means of the cord attached to the ring on its topmost point, and turned until the gnomon faces the sun. The shadow of the gnomon then lies in a straight line down the side of the cylinder, parallel to its axis, and the time is indicated by the position of the lowest point of the line —the shadow of the tip of the gnomon.

When not in use, the gnomon can be folded up and inserted inside the body of the dial, the cap being removable.

The left-hand sundial dates from the second half of the 17th century or possibly a little later, and is designed for use in a latitude of 46°. The sundial on the right, which probably dates from about the same period, bears a map of Bavaria and is designed for a latitude of about 48°; as it was without a gnomon when received the gnomon shown was made up in the Museum. Inv. 1938–22 and 23, Photos 189/38, 190/38.

56. WOODEN COLUMN SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This large 17th-century sundial indicates hours a.m. and p.m., and bears a painted figure of St. Christopher.

The base can be rotated so as to show the time in various parts of the world when it is known at some standard place. Inv. 1938–353.

57. TIBETAN PRIEST'S TIME-STICK.

This instrument, from Darjeeling, is similar in principle to a column sundial.

It is provided with eight time scales, and to find the time the wire gnomon is plugged into the horizontal hole at the top of the scale corresponding to the month in question and the stick is turned until the shadow of the gnomon falls straight down the scale, the time being then shown by the lower end of this shadow.

Inv. 1952–442, Photos 503/53, 504/53.

HORIZONTAL AND ANALEMMATIC DIAL

58. HORIZONTAL AND ANALEMMATIC SUNDIAL. Made by Engelbrecht, Beraunae in Bohemia, 1784.

With a combination of these two types of dials it is possible, by turning the instrument until both dials indicate the same time, to dispense with the use of a compass for setting. It is, however, necessary to know whether the sun is east or west of the meridian as similar readings on the two dials can be obtained in two positions corresponding to equal altitudes of the sun.

The horizontal dial has a folding gnomon for a latitude of 51° and, in addition to the ordinary hour lines, there are curves indicating the paths at different times of the year of the shadow of a notch in the edge of the gnomon.

In an analemmatic dial the hours are indicated by the intersection of the shadow of a vertical gnomon and an elliptical scale of hours. The gnomon has, however, to be adjusted in a north and south direction according to the time of the year.

A plummet and scale allows the instrument to be set for latitudes between 40° and 60°.

Inv. 1894–10.

PORTABLE UNIVERSAL ALTITUDE DIALS

59. UNIVERSAL RING SUNDIAL.

This 18th-century instrument is of French make and indicates the time by light from the sun passing through a pin hole on to a graduated ring parallel to the earth's equator.

The pin hole is in a piece which slides along an axial bar parallel to the earth's axis, and the position of the pin hole is adjusted daily to correspond with the changes in the sun's declination. The equatorial ring and the axial bar are mounted inside a ring, which is set in the meridian and which itself slides within an outer meridian ring. The latter is fixed to the base of the instrument but the inner meridian ring carries a scale of latitudes of various places and can be adjusted for any latitude.

In use the pin hole is set to the date and turned to face the sun; the whole instrument is then rotated about a vertical axis until the spot of light passing through the pin hole falls exactly upon the hour circle, where it indicates the time. Inv. 1880–29.

60. PORTABLE UNIVERSAL RING SUNDIAL. Presented by A. R. T. Woods, Esq.

This instrument was made by Cary about 1800 and resembles the adjacent example (Catalogue No. 59), in which the time is indicated by the sun's rays passing through a pin hole, the resulting spot of light falling upon a circular scale of hours. The position of the pin hole has first to be adjusted to the correct date, and the dial is then suspended from the thumb or finger and rotated about a vertical axis until the spot of light falls exactly upon the hour circle. In general, two possible positions will be found, one showing a time before noon and one an equal number of hours after noon.

In order to ascertain whether the time is before or after noon (if not already known) a second observation must be made after an interval of several minutes.

The uncertainty is due to the fact that the time is actually found from the sun's altitude in the heavens, and for the same reason the time cannot be found accurately in the neighbourhood of noon itself, when the sun's altitude is changing only slowly.

Inv. 1932–553, Photo 7243.

61. UNIVERSAL SUNDIAL. Presented by Messrs. C. F. Casella and Co., Ltd.

This instrument consists of an equatorial dial arranged to indicate the time by pointers showing hours and minutes. It is inscribed "Filippo et Hover. Fratelli De Bianchy No. 8, 1764."

The dial is hinged to the base plate to allow of adjustment for latitude and bears a pointer on which a sighting system is carried. The latter consists of a pin hole and a small disc mounted on a hinged arm which can be moved perpendicularly to the plane of the dial and so adjusted for the declination of the sun, a sector marked with dates being provided.

In use, the spot of light from the pin hole is made to fall on the centre of the disc. The pointer then indicates the hours on a scale on the dial. The outer edge of the dial is toothed and gears with a pinion which is mounted on the tail end of the pointer and carries a hand which moves over a scale of minutes. When adjusting the position of the spot of light this hand is moved by a small key. Inv. 1923–404.

62. WHEATSTONE'S SOLAR CHRONOMETER. Made by Elliott, London. Presented by T. H. Court, Esq.

In this instrument the time is indicated on a dial by hour and minute hands as in an ordinary watch.

Mounted on bearings on a polar axis there is a tube with a lens at the end, and when this tube is so adjusted that an image of the sun falls on the centre of a system of concentric circles the hands show the time.

Two scales with verniers are provided, one for setting the polar axis for latitude and the other for adjusting the tube for the sun's declination. The dial is fixed on the polar axis, while the hands are connected by gearing with the tube. A spirit level and three levelling screws are provided and the minute scale is divided into 10-second divisions.

Inv. 1921–816, Photo 7242.

POCKET COMPASS DIALS

63. POCKET SUNDIAL.

This French or Italian dial was made about 1600 and consists of a bronze cup containing a magnetic needle and carrying a horizontal dial on its rim.

A small folding gnomon for a latitude of 43° is mounted over the mouth of the cup.

Inv. 1883–127.

64. HORIZONTAL SUNDIAL. Made by N. Bion, Paris.

This pocket 18th-century dial has a folding gnomon for use at a latitude of 42° and includes a magnetic compass for setting.

In addition to the ordinary hour scale, there are scales for showing Babylonian and Italian hours, which are indicated by the shadow of a notch in the gnomon.

Round the margin of the dial there are the names of various places, each of which is arranged according to the time at Rome when it is noon at the place. Inv. 1883–137.

65. POCKET EBONY CUP SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This small pocket compass dial indicates Italian hours, the time being shown by the shadow of the tip of the pointed gnomon. Inv. 1938–349.

66. POCKET BRASS DISC SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This pocket compass dial is designed for use in a latitude of 43°, and the time in Italian hours is shown by the position of the shadow of the tip of the gnomon.

Inv. 1938–350.

67. POCKET SUNDIAL AND COMPASS. Presented by T. H. Court, Esq.

This was made by Walker and Son, Dublin, in the early part of the 19th century. It has a folding gnomon for a latitude of 51½° and is enclosed in a brass box. Inv. 1918–95.

68. HORIZONTAL SUNDIAL.

This 19th-century dial automatically sets itself horizontally, with its gnomon in the meridian.

The dial and gnomon are supported by means of an agate bearing, on a vertical needle, and attached to the under side of the dial there is a magnetized rod, the position of which can be adjusted for variation. Inv. 1887–13.

69. SUNDIAL. Presented by Dr. Herbert Chatley, Shanghai.

This is a small, relatively modern Chinese sundial made of wood.

The gnomon is a hinged pin and is set at right angles to the plane of the dial, the inclination of which can be varied. At the summer solstice the dial plane is at its maximum inclination and is approximately in the equatorial plane. If it were kept in this plane no readings could be obtained when the sun was south of the equator, but as the sun moves southwards the inclination of the dial is decreased until it is a minimum at the winter solstice. The dial is adjusted by means of a hinged strut moving over a notched scale of seasons of the year. With this arrangement there are, of course, considerable errors in the time readings.

The instrument includes a magnetic compass and can be folded flat. It is for use at a latitude of about 35° N. Inv. 1928–207, Photos 559/37, 595/37, 560/37.

TABLET COMPASS DIALS

These form a special type of pocket compass dial consisting of two rectangular tablets of metal, ivory or wood hinged together. In some of them the shadow is cast by a tautened string when the dial is opened out for use.

70. IVORY TABLET SUNDIAL (see Plate IV). Made by Hans Ducher, 1574.

The shadow of the string gnomon shows hours a.m. and p.m. on the circular horizontal dial and the semi-circular central vertical dial, while the shadows of the tips of the two short pointed styles show Italian hours on their respective dials.

Inv. 1952–235, Photo 477/53.

71. BRASS TABLET SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This tablet sundial is signed "V.S." (Ulrich Schniep of Munich) and is dated 158–; it is intended for use in a latitude of 48°. On the outer surface of the lid is a calendar.

Inv. 1938–364.

72. TABLET SUNDIAL.

This gilt-metal folding pocket sundial is of German make and is dated 1597.

It is designed for use at a latitude of 50°, and the shadow of a string gnomon indicates the time upon a horizontal dial which surrounds a magnetic compass.

A small vertical style on the base indicates Italian hours, and a horizontal style inside the lid shows Italian hours, Babylonian hours, and the lengths of the day and the night. Below this there is a dial which, as a vertical south dial, shows ordinary "equal" hours and, in conjunction with a bead on the string gnomon, indicates the planetary or Jewish hours, and shows the sun's place in the ecliptic.

The top outside of the lid is engraved with the points of the compass and carries a pointer, while a hole in the lid enables the inside magnetic needle to be seen for the purpose of taking a bearing.

On the bottom there are circular tables giving Julian and Gregorian epacts from the years 1597 to 1615 and also a lunar circle indicating the moon's phase and time of southing according to its age. Inv. 1883–140, Photo 27/47.

73. TABLET SUNDIAL.

This 17th-century German sundial has a string gnomon, the shadow of which serves to indicate the time on a plane horizontal dial on the base and on a vertical south dial on the opened lid.

In addition, Italian hours are shown on a small metal dial with a vertical style. The instrument is made of ivory and its exterior is engraved with religious pictures.

Inv. 1880–55.

74. TABLET SUNDIAL.

This engraved ivory pocket sundial is of German make and is dated 1648.

It has a string gnomon which can be adjusted for five different latitudes and five corresponding hour scales are provided on the horizontal dial. In addition there are two small vertical styles reading Italian and Babylonian hours respectively and a small horizontal style showing equal hours on a dial at the top of the opened lid. This dial also indicates the length of the day and the position of the sun in the zodiac.

On the outside of the lid there is a compass dial which, in combination with a rotating pointer and a hole in the lid through which the inside compass needle could be seen, allowed a bearing to be taken.

Formerly the instrument had a wind vane which when in use was placed in a hole in the middle of the compass dial and when not in use was stored in a recess in the side of the base. Inv. 1880–54.

75. WOODEN POCKET SUNDIAL. Presented by T. H. Court, Esq.

This 18th-century dial is of the folding tablet form in which the same string constituted the gnomon of a plane horizontal dial and a vertical south dial.

A series of holes is provided through which the string can be threaded for various latitudes. Inv. 1914–887.

76. ITALIAN IVORY TABLET SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This sundial shows Italian hours. The cup dial is for use in the latitude of Venice (45°), while the vertical dial on the inner surface of the lid is for use in the latitude of Rome (42°). Inv. 1938–354, Photo 419/38.

77. TABLET AZIMUTH SUNDIAL. Made by Carolus Bloud, Dieppe.

This 17th-century ivory pocket instrument indicates the times by the azimuth of the sun.

Underneath a compass needle there is an elliptical scale of hours which is adjusted in position for the time of year by turning a plate on the underside of the base. In use the whole instrument is turned until the shadow of the open lid falls symmetrically on the base, and the point of the needle then indicates the time, the hour scale being so arranged as to compensate for the magnetic variation.

The lid itself serves as an equatorial dial, a scale of latitudes, marked on the right edge of the lid, being used in combination with a hinged prop to set it at the proper inclination. The time is then shown by the shadow of a movable style on hour circles on the faces of the lid.

Inside the lid there are revolving plates for lunar calculations.

Inv. 1880–53, Photo 346/53.

POCKET UNIVERSAL COMPASS DIALS

78. UNIVERSAL POCKET SUNDIAL.

This is inscribed "Juan. Cocart. me. fe. 1596" and has a pin gnomon and equatorial hour circle.

A scale along the side in conjunction with a small prop allows the circle and pin to be set for different latitudes. When folded up the whole is enclosed in a small square gilt-metal case. Inv. 1883–122, Photo 28/47.

79. UNIVERSAL POCKET SUNDIAL. Made by Lorenz Grasl, Augsburg.

This is a 17th-century instrument with polar pin gnomon and equatorial hour circle.

Inv. 1888–175.

80. UNIVERSAL POCKET SUNDIAL. Made by Johann Martin, Augsburg.

This early 18th-century dial is provided with a pin gnomon and an equatorial hour circle, and the latter is so connected with a small pointer moving over a scale of degrees that by turning the pointer, the instrument can be adjusted for latitudes between 25° and 65°.

The instrument, which includes a magnetic compass, can be folded up and is enclosed in a silver case like a watch. Inv. 1883–121.

81. POCKET SUNDIAL. Made by Baradelle, Paris.

This is of the "Butterfield" type and dates from the early 18th century. Though not strictly "universal" it can be used over a range of latitudes. The gnomon can be adjusted for use in any latitude between 40° and 60° and the dial plate carries four distinct scales of hours suitable for latitudes 40°, 45°, 49° and 52° respectively.

The compass is provided with a special scale reading from 0° to 20° of arc so that the magnetic declination can be accurately allowed for. On the underside of the dial is a table giving the latitudes of 27 important towns in various European countries.

Inv. 1938–107, Photo 188/38.

SAXON POCKET DIAL

82. TENTH-CENTURY SAXON POCKET SUNDIAL. (Copy.)

The original dial, of which this is a copy, was found in 1939 in the soil of the Cloister Garth at Canterbury Cathedral. It was in the form of a tablet of silver with a gold cap and chain. The gnomon consisted of a gold pin surmounted by a chased animal head with jewelled eyes and a ball in the mouth.

To use the dial, the gnomon is inserted in the hole corresponding to the month in question, the dial is suspended by the chain and turned to face the sun, the position of the shadow of the tip of the gnomon being noted.

Two dots will be seen in each month column; the lowest of these corresponds to the position of the tip of the shadow at noon, the upper dot corresponding to an intermediate time roughly half-way between noon and sunrise or sunset.

It is known that the Saxons divided the daylight periods into four "tides" of roughly equal lengths, and the positions of the upper dots correspond therefore roughly with the end of the first and third tides (noon being the end of the second tide).

The time indications are quite rough, and it will be noted that the upper dot for May is lower than that for June, which is the reverse of what we should expect.

The instrument measures time by the sun's altitude and is similar in many ways to the later column or cylinder dials in which the hour scales are wrapped round a cylinder instead of engraved upon two plane surfaces.

When not in use the gnomon can be inserted in a hole in the bottom of the tablet.

The sides of the dial are inscribed in Latin "PAX POSSESSORI" and "SALUS FACTORI"; which may be freely translated "God rest my owner," "God bless my maker."

This copy of the original dial has been made by kind permission of the Dean and Chapter of Canterbury Cathedral. Inv. 1950–10, Photos 204/50 to 208/50.

POCKET DISC DIAL

83. POCKET SUNDIAL AND PERPETUAL CALENDAR. Made by Johan Henrich Börner, 1693.

This consists of a combination of a vertical disc sundial and a perpetual calendar.

To set the sundial for use the arm is rotated until it is opposite the correct month and the gnomon is lifted from its socket until it stands out perpendicular to the face of the dial. The instrument is then suspended from a small shackle (now broken off) and turned until the shadow of the tip of the gnomon falls upon the scale of hours, where it indicates the time. The instrument is similar in principle to a ring dial, the tip of the gnomon corresponding to the hole in the ring.

On the reverse side of the instrument is a perpetual calendar showing the times of sunrise and sunset and the length of the day and of the night for each month of the year. A weekly calendar is also included.

The instrument is designed for use in a latitude of about 54°, that of the most northerly part of Germany. Inv. 1938–337.

POCKET QUADRANT DIALS

84. BRASS QUADRANT SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This 16th-century instrument shows "planetary" or "Jewish" hours on the small scale, and Italian hours on the main, large scale. Inv. 1938–358, Photo 14/51.

85. IVORY QUADRANT SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This 17th-century dial is designed for use in a latitude of 44°, and indicates Italian hours. Inv. 1938–356, Photo 15/51.

POCKET COLUMN DIALS

86. POCKET IVORY COLUMN SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This is a 17th-century French instrument, indicating hours a.m. and p.m.

Inv. 1938–368.

87. POCKET IVORY COLUMN SUNDIAL. Made by D. Stephanus, 1587.

This column dial is similar in principle to the larger instruments shown in a neighbouring case (Catalogue Nos. 53–56) but is designed to indicate time on the old Italian system, in which the day-and-night period is divided into 24 equal parts, starting from sunset. On this system the hours 1 to 8 always occur during the night, and it will be noticed that these hour-numbers do not occur on the dial exhibited, the smallest hour-number being 9.

Two alternative gnomons are provided—a short one for use in the summer months and a long one for the winter months when the sun is relatively low in the heavens. Either or both of these gnomons can be folded up and contained within the body of the instrument.

As in other column dials, the gnomon is first set for the season of the year and turned to face the sun and the time is then read off from the position of the shadow of the tip of the gnomon; the time is shown on the scale of the red lines before noon and on the scale of the black lines after noon.

The sundial is designed for use in a latitude of about 43°.

Inv. 1937–832, Photos 662/37, 663/37.

88. PORTABLE "SHEPHERD'S" COLUMN SUNDIAL. Presented by T. H. Court, Esq.

This sundial is of a type which was in common use until recently in the Pyrenees. It is in principle similar to the adjacent column dial (Catalogue No. 87), in which the time of day is found by measuring the sun's altitude.

The dial, which is designed for a latitude of 42°, was probably made in the 19th century, and is of very rough construction, the time-scales being only approximately correct.

When the dial is not in use the cap carrying the gnomon can be removed, the gnomon rotated through 90° in a vertical plane, and the cap replaced with the gnomon contained entirely within the body of the dial. Inv. 1934–137, Photo 8232.

POCKET RING DIALS

89. POCKET RING SUNDIAL (see Plate IV).

This is inscribed "S.P.F. 1736" and indicates the time by means of the altitude of the sun.

It consists of a brass ring 2·1 in. in diameter and 0·8 in. wide which in use is suspended vertically from a shackle on its rim and turned about a vertical axis until light from the sun passes through a pin hole in the middle of the rim on to the interior of the ring. Inscribed on the latter are a series of vertical circles corresponding to the time of the year and when the spot of light falls on the proper position, the time is given by reference to a series of inclined hour lines.

This example has two pin holes for use in summer and winter respectively, and the vertical circles are consequently further apart than if one hole only was used.

Round the outside of the ring is a table showing the sun's place in the zodiac at different times of the year. The instrument appears to have been made for latitude 51° 30′.

Inv. 1894–12, Photo 8231A.

90. POCKET RING SUNDIAL.

This is dated 1716 and is similar in principle to the adjacent portable ring dial (Catalogue No. 89), except that it has one pin hole which is adjusted in position for the time of the year and thus allows the hour scale to take the form of a series of straight lines parallel to the axis of the ring.

The pin hole is made in a small ring which is mounted coaxially on the middle of the main ring, round the rim of which it can be turned. The main ring bears a scale of dates and is slotted where necessary to permit the passage of light. This instrument is for use at a latitude of about 48°. Inv. 1894–11, Photo 8231.

POCKET UNIVERSAL RING DIALS

91. POCKET UNIVERSAL RING SUNDIAL. Presented by T. H. Court, Esq.

This early 18th-century instrument has an equatorial hour circle and a polar axis carrying a pin hole, the position of which is adjusted according to the time of the year.

When adjusted, the instrument is suspended by means of a shackle and the time is indicated when the rays passing through the pin hole fall exactly on the equatorial hour circle.

The shackle is mounted upon a piece which can be made to slide round an outer circle and is thus adjusted in position for the latitude of observation, the necessary scale being provided. The instrument can be folded flat. Inv. 1919–324.

92. POCKET UNIVERSAL RING SUNDIAL. Presented by W. E. Miller, Esq., F.S.A.

This instrument is of German origin, and, like the larger and more refined instruments exhibited nearby, is adjustable for use in any latitude. Inv. 1938–372.

93. UNIVERSAL SUNDIAL. Made by Johan Martin, Augsburg.

This late 17th-century dial has a crescent-shaped gnomon, the position of which is adjustable according to the season of the year, and the time is shown when the shadow of one of the tips of the gnomon falls exactly upon the central line of one of the two arcs of equatorial circles. The dial is exactly similar in principle to the adjacent universal ring-dials, the pin hole being replaced by the tip of the gnomon and the hour-ring being divided into two portions placed back to back instead of forming a complete circle.

The inclination of the dial can be adjusted for use in different latitudes and a small plumb-bob is fitted for levelling purposes. The various parts can be folded flat for carrying.

On the underside of the sundial is a simple perpetual weekly calendar. Inv. 1943–20.

MEAN-TIME DIALS

94. SUNDIAL SHOWING MEAN TIME. Made by Negretti and Zambra. Presented by Miss M. B. L. Oliver.

This sundial, patented by Major-General Oliver in 1892, is designed to indicate mean time directly, the equation of time being automatically allowed for by the shape of the style which casts the shadow.

This style consists of a metal plate from the central part of which a figure has been cut out. The time is indicated by the point at which the shadow of the curved edge of the plate intersects the equatorial line on the hour circle, and the plate is marked with the names of the months to show which side of the shadow is to be observed.

The hour circle is engraved with divisions every five minutes, and the instrument can be adjusted for any latitude between 60° N. and 60° S.

[See British Patent Specification No. 1660 of 1892.] Inv. 1897–29, Photo 7263.

95. FERGUSON'S SOLAR CHRONOMETER. Lent by Messrs. J. H. Steward, Ltd., 406, Strand, W.C.

This is an example of a relatively modern universal sundial arranged to correct for the equation of time.

Two pointed rods parallel to the polar axis, with their points close together, throw a shadow on to a card which is mounted in a frame forming part of a cylinder of which the rods are the axis.

On the card there is a series of curved lines corresponding to the times at which the shadow of the points crosses the lines, and the latter are so shaped as to include corrections for the equation of time. The point on a line where the shadow crosses it on any day depends on the sun's declination and it is necessary to employ two cards, one for use from June 22nd to December 22nd when the sun is moving south, and one for the other half of the year.

A scale is provided for use in moving the card sideways to correct for longitude and thus obtain standard instead of local time, and the inclination of the instrument can be adjusted for different latitudes by means of a sector and plummet. Inv. 1922–104.

96. UNIVERSAL HELIO-CHRONOMETER. Made and lent by Messrs. Pilkington and Gibbs, Ltd., Preston.

This is a relatively modern equatorial sundial which is arranged to correct for the equation of time and to indicate mean time directly. It is also adjustable to give standard instead of local time.

Mounted on an equatorial disc which turns on a polar axis there is a sighting system consisting of two plates perpendicular to the disc. The disc is turned until the light from the sun passes through one or other of two small holes in the first plate on to a line on the other plate and the time is then indicated on the circumference of the disc by a fixed index. To allow for the correction for the equation of time the first sighting plate can be moved sideways by means of a cam which is operated by a second disc mounted on the main disc and bearing a scale of dates.

A quadrant is provided for setting for latitude. Inv. 1922–156.

NOCTURNALS

97. NOCTURNAL. Presented by J. McGregor, Esq.

This wooden instrument, made about 1700, is intended for use in finding the time by night from the positions of the "pointers" of the Great Bear or of the bright star of the Little Bear.

It consists of a circular plate with a handle and carries a scale of dates marked on its outer edge. Revolving on this plate there is a smaller plate marked with a scale of hours and carrying two projecting teeth marked "G" and "L" respectively. Moving on the same axis as the revolving plate there is a long pointer which projects out beyond both plates.

In use, the inner revolving dial is first adjusted for the day of the year, the projection marked "G" being set to the date if the Great Bear is to be observed and the projection "L" if the Little Bear. The instrument is then held parallel to the plane of the equator with its centre line in the meridian, and the Pole Star is viewed through the hole in its axis. The long pointer is then turned until its edge is in line with the particular star to be observed and the time is then indicated by the reading of the edge of the long pointer upon the hour scale of the inner plate.

The back of the instrument bears scales giving the correction to be applied to obtain the latitude from the altitude of the Pole Star, the particular figure to be used being indicated by the position of the long pointer. Inv. 1933–408, Photo 7262.

98. DIAGRAM SHOWING A NOCTURNAL IN USE. Inv. 1937–42, Photo 32/47.

PERPETUAL CALENDARS

99. PERPETUAL CALENDAR.

This 18th-century French calendar has two rotating plates which are slotted to show portions of scales below.

By adjusting the lower plate for the month, indications are given of the sun's position in the zodiac, the lengths of the days and nights in hours, and the times of sunrise and sunset. The upper and smaller plate can be set so that the days of the week correspond with the dates of the month. Inv. 1880–44.

100. PERPETUAL CALENDAR.

This is of 18th-century German make and shows the phases of the moon according to its age. Inv. 1883–120.

101. ENGLISH PERPETUAL CALENDAR. Inv. 1938–377.

102. SILVER GERMAN PERPETUAL CALENDAR. Inv. 1938–380.

LATE ADDITION

102a. SOUTH GERMAN CUP, GOBLET OR CHALICE SUNDIAL.

This is in the form of a chalice, with the hour-lines engraved on the inside, and the time is shown by the shadow of the tip of the vertical gnomon.

This dial is dated 1596, and shows Italian hours, equal hours and temporal hours. It is for use in lat. 42°.

Inv. 1955–149, Photos 421/55, 422/55, 423/55.

III. MECHANICAL CLOCKS

ALL METHODS of measuring time are based upon the utilisation of some form of regular motion, by means of which the passage of time is translated into the traversing of space.

Mechanical timekeepers make use of some form of cyclic mechanical motion which repeats itself over and over again. In the earliest mechanical clocks a pivoted beam or "foliot" was pushed first in one direction and then in the other by means of a toothed wheel driven by a weight, the wheel escaping through the pitch of one tooth at each double swing. Much greater regularity and accuracy can be attained by the use of a natural cyclical motion such as the oscillation of a pendulum swinging under the attraction of gravity.

A pendulum clock consists of a train of wheels driven by a weight or spring, the rate of rotation of the wheels being limited by an "escapement" which allows one tooth of a toothed wheel to escape at each swing of the pendulum, while in the act of escaping the tooth gives an impulse to the pendulum by means of some simple connecting system, the impulse being necessary to make good the pendulum's loss of energy due to air resistance. The clock mechanism effectively counts the swings of the pendulum and records their number upon the dial.

The weight-driven clocks in the Museum Collection are divided into the following main groups:

(1) Turret clocks, *i.e.*, large public clocks for use in bell-towers or turrets.

(2) Domestic clocks.

(3) Regulators, *i.e.*, clocks specially designed for very accurate time-keeping.

The collection also includes a clock showing sidereal time together with several models of the escapements employed in clocks.

Spring-driven clocks are included with watches in the next chapter.

TURRET CLOCKS

103. 14TH-CENTURY CLOCK IN SALISBURY CATHEDRAL. From photographs lent by R. P. Howgrave-Graham, Esq., F.S.A.

This is probably the oldest clock in England, for there is evidence that it dates from 1386 or a little earlier. It was originally installed in a 13th-century bell-tower in the Close at Salisbury, but on the demolition of the bell-tower in the 18th century it was removed to the Cathedral tower and continued working there until 1884, when it was replaced by a new clock. It remained unnoticed until 1928, when it was re-discovered by Mr. T. R. Robinson, and in 1931, at the instigation of Mr. Howgrave-Graham, it was taken to pieces, cleaned and re-assembled in the North Aisle of the Nave where it is now to be seen. Both the photographs exhibited were taken in the tower in 1929.

The clock bears a remarkable resemblance, both in general and in details, to the Wells clock which was probably constructed about 1392 and is now in this Museum (see Catalogue No. 104). Each of the two clocks was originally controlled by a verge escapement and foliot balance, but each has been altered at some time so as to employ a pendulum. The Salisbury clock possesses a going and a striking mechanism, while the Wells clock chimes the quarters in addition.

The framing and wheels of the Salisbury clock are constructed of wrought iron and the framework is fastened together by mortices, tenons and cotters, there being no screw fastenings.

No dial has survived at Salisbury, and it is possible that the clock was intended solely for striking the hours.

[See R. P. Howgrave-Graham, "The Practical Watch and Clock Maker," Vol. 2, p. 445 (Nov. 1929).] Inv. 1935–629.

104. 14TH-CENTURY CLOCK. Formerly in Wells Cathedral. Lent by The Dean and Chapter of Wells Cathedral.

According to a tradition which is no longer accepted as reliable, this clock was said to have been made about 1325 by Peter Lightfoot, a resident monk at Glastonbury Abbey, and to have been removed from there to Wells Cathedral about 1540. Records, however, have been found showing that there was a clock in use at Wells in 1392, and it appears probable that this clock was made for Wells Cathedral before that date.

The Wells clock movement continued in use until 1835, when it was replaced by a modern one, and the old movement was removed to the crypt of the Cathedral. In 1871 it was lent to the Patent Office Museum, where a few new brass wheels were made to take the place of original iron ones, which had been lost, and the clock has since been on public exhibition in working order. Originally it was controlled by a verge escapement with a foliot balance, but some time after the introduction of the pendulum in the latter half of the 17th century an anchor escapement and pendulum were substituted. The framing and wheels are of wrought iron and the framework is fastened together by mortices, tenons and cotters.

The striking portion is driven by separate weights and is of the locking-plate type still used in turret clocks. It strikes the hours and chimes the quarters.

The new movement at Wells was adapted to the dial and moving figures previously employed, but some of these include features which do not date back to the 14th century. There is an interior dial indicating the hours and minutes, and the age and phases of the moon. Above it there are figures representing four knights on horseback, and every hour two on one side charge the others in tournament fashion, one being unseated on each occasion. Inside the cathedral there is a figure known as "Jack Blandifer," which strikes bells at the quarters with its heels and the hours with a hammer held in its hand. There is also an exterior dial above which there are two quarter-jacks about 4 ft. in height.

[See "Peter Lightfoot and the Old Clock of Wells," by R. P. Howgrave-Graham; also "Archaeologia," vol. 77.] Inv. 1884–77, Photos 193, 194, 166/52.

105. PHOTOGRAPHS RELATING TO THE CLOCK AT WELLS CATHEDRAL. Presented by R. P. Howgrave-Graham, Esq.

These show the dials and moving figures still used at Wells Cathedral in association with a modern clock movement. Inv. 1922–706.

106. DOVER CASTLE CLOCK. Lent by the War Office.

This was removed from Dover Castle in 1872 and is of special interest in being one of the only two known public clocks still retaining the original form of verge escapement with the foliot or crossbar balance which appears to have been introduced in the 14th century and was the only means employed for controlling mechanical clocks until the application of the pendulum 300 years later.

No definite information is now available concerning the origin of this clock, but there is an unreliable tradition that it is of Swiss origin and also that it was made in 1348. Records show that payments were made for the maintenance of a clock at Dover Castle as early as 1404–7 but recent research has cast much doubt on this early date, and it now appears probable that the clock was made in the late 16th or early 17th century, though in design and workmanship it resembles a 14th-century clock. The traditional date, 1348, may relate to bells which were installed about that time.

The verge escapement has a crown wheel with pointed teeth which engage with two projections or "pallets" on a vertical spindle or "verge" on which the "balance" is mounted, the action causing the balance to vibrate to and fro, while the wheel moves forward under the action of the driving weight through the space of half a tooth for each swing. The rate of a clock fitted with a mechanism of this type depends very largely upon the amount of the driving weight and on the shaping of the teeth of the crown wheel; it is also greatly affected by variations of friction in the driving mechanism. In order to reduce friction the cross-bar balance is partly suspended by a cord, while regulation is effected by altering the position of the movable weights hanging from the cross-bar.

The going train of the clock consists of two wheels only, a main wheel of 96 teeth driving an escape wheel pinion of 7 teeth, with an escape wheel of 33 teeth. The main wheel rotates once an hour and the balance makes a double swing in about 8 seconds.

A locking-plate striking mechanism, driven by a separate weight, is actuated by a pin on the main wheel, and strikes the hours.

The going train is wound up by means of four radial arms on the barrel, while the

Clement's Turret Clock with Anchor Escapement, 1671
(Cat. No. 107).

Augsburg Astrolabe Clock, early 17th Century
(Cat. No. 153).

PLATE V

PLATE VI

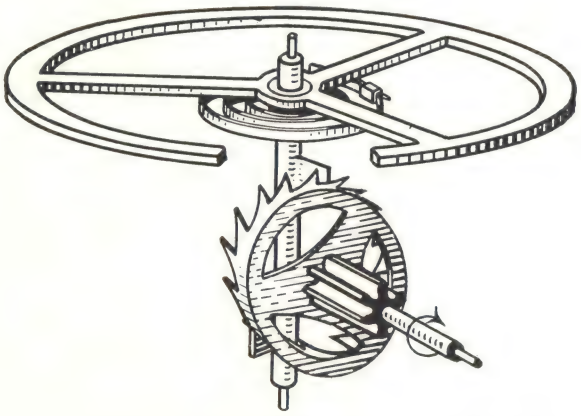


Diagram of Verge Escapement (Cat. No. 161).

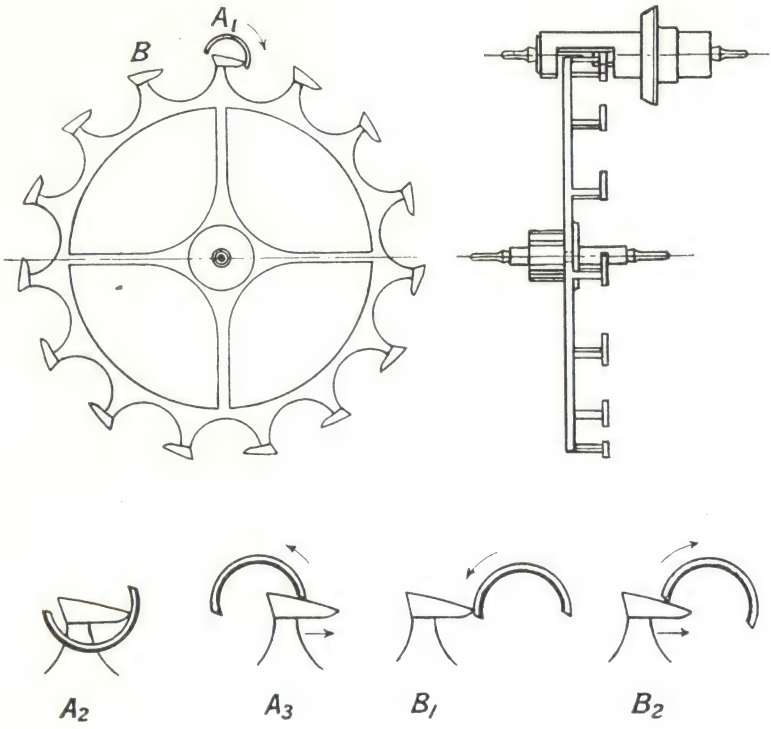


Diagram of Cylinder Escapement (Cat. No. 205).

PLATE VII

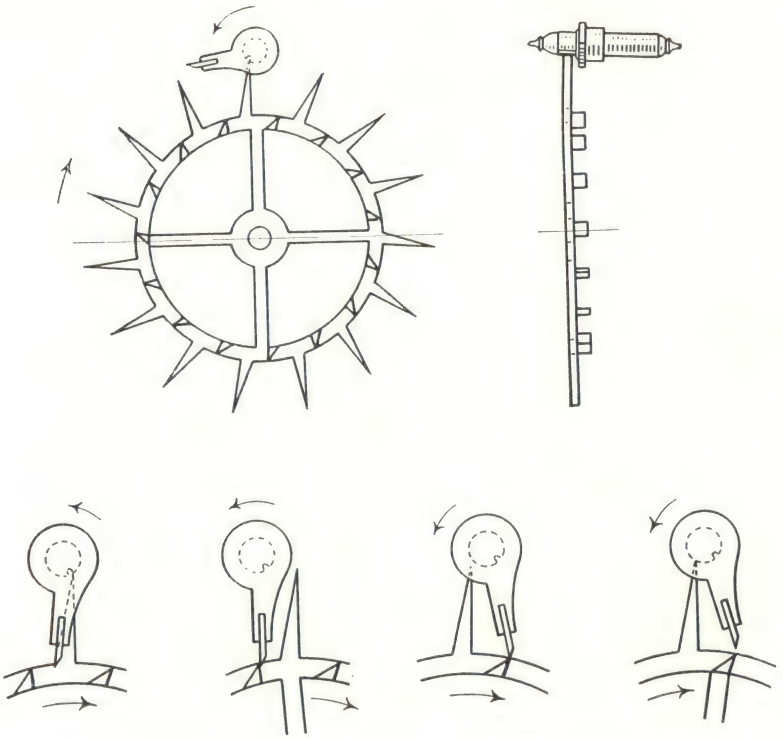


Diagram of Duplex Escapement (Cat. No. 227).

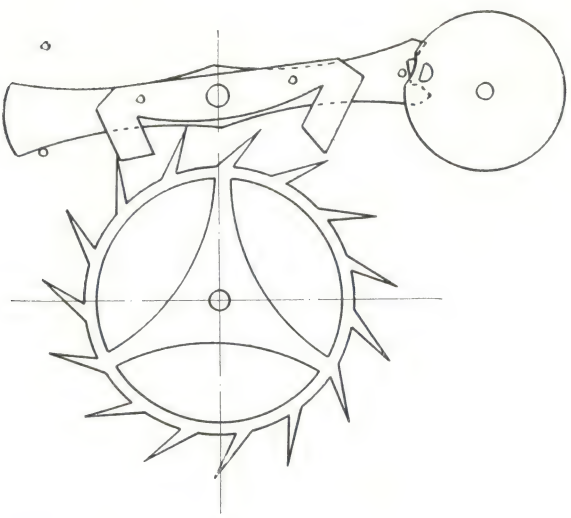


Diagram of English Lever Escapement (Cat. No. 243).

PLATE VIII

Watch with wandering hour-figure by William Crayle, about 1660 (Cat. No. 277).

(By courtesy of Messrs. C. Fordsham and Co., Ltd.)

Marine Chronometer by John Arnold and Son, about 1800 (Cat. No. 342).

striking train has a modified arrangement, but in both cases the clicks lock against the spokes of the wheels and no rachet wheels are used.

The wheels and frame are of wrought iron, and the framework is secured together by cotters, there being no screw fastenings. The pinions are solid.

[See R. P. Howgrave-Graham, "The Watch and Clock Maker," vol. 4, p. 52 (1931).]

Inv. 1884–81, Photo 97.

107. 17TH-CENTURY TURRET CLOCK (see Plate V). Presented by the Rev. C. C. H. James.

This clock, from St. Giles' Church, Cambridge, is of special interest as an early example of the use of the anchor or recoil escapement. It was made by William Clement, London, in 1671, and was at King's College, Cambridge, until 1817, when it was transferred to St. Giles' Church.

The invention of the anchor escapement rendered practicable the successful application of the pendulum to the purposes of time keeping, as this escapement required a smaller arc of vibration than the modification of the verge escapement previously employed, and so easily permitted the use of a longer pendulum giving much greater accuracy. The earliest examples were made by William Clement, for whom as well as for Dr. Robert Hooke the credit of the invention has been claimed. Although the recoil form of the anchor escapement is not now used for clocks for which a high degree of accuracy is required, it is the form most extensively employed.

In the clock shown the going and striking trains of wheels are mounted side by side in an iron frame the members of which are secured together by screw nuts. A locking plate mechanism is provided to strike the hours and the clock is fitted with a maintaining power mechanism of the bolt and shutter type to drive it during the process of winding. Alterations have probably been made in the clock since 1671, and some of the brass wheels appear to be of a later date.

The pendulum makes 47·25 vibrations a minute and is of the type formerly known as "royal" owing, it is said, to its having "dominion" over the clock.

Inv. 1925–704, Photos 3070, 3071.

108. TURRET CLOCK. Presented by the Metropolitan Police.

The setting-dial of this clock movement is signed "Vulliamy, London, 1795," and the clock was formerly in the pediment of a building in Great Scotland Yard which formed part of the headquarters of the Metropolitan Police before the present building was erected in 1894.

The timekeeping is controlled, through an anchor escapement, by a pendulum making one beat in 1 8/27 seconds and a maintaining power of bolt-and-shutter type is provided. The setting-dial reads both hours and minutes and its hands rotate anti-clockwise. The striking mechanism is of the rack type. Inv. 1939–320.

109. MODERN TURRET TIMEPIECE WITH GRAVITY ESCAPEMENT. Made and lent by Gillett and Johnston, Ltd., Croydon.

This is fitted with Grimthorpe's double three-legged gravity escapement, which is the escapement now generally used in weight-driven turret clocks. It was invented by Mr. E. B. Denison (afterwards Lord Grimthorpe) about 1854 and was employed in the Westminster clock ("Big Ben") made at that time.

As in other gravity escapements, the impulses are not given to the pendulum directly by the wheel train, but by means of two gravity arms which are raised through equal amounts by the train. The impulses to the pendulum consequently remain constant even if the load on the train varies considerably, as it does in turret clocks in which the outside hands are exposed to the weather.

There are two escape wheels mounted on one axis and each has three long teeth or legs. In the space between the wheels there are three lifting pins which engage with pallets mounted on two hinged arms. The latter constitute the gravity arms and each carries a locking face, while pins at the lower ends embrace the pendulum.

As the pendulum swings, say, to the right, it carries the right-hand locking face with it and releases the wheels, which move until stopped by the left-hand locking face. During this process the left-hand gravity arm is lifted through a small angle by the engagement of one of the lifting pins with its pallet and the amount by which the arm is so raised constitutes the impulse for the next swing to the right. This raising of a gravity arm can be seen when the arm which has been following the pendulum moves in the opposite direction at the end of a swing.

Though similar in principle to the Bloxam gravity escapement which is fitted to one of the clocks in this Gallery, Grimthorpe's arrangement differs in the addition of a fly, which is mounted on the escape wheel axis for the purpose of preventing violent collisions between the teeth and the locking faces.

The timepiece shown has a nickel-alloy compensation pendulum beating seconds, and is automatically wound through an endless-chain arrangement by means of an electric motor. As the driving weight falls the subsidiary chain rotates a pulley which tips a mercury switch in the motor circuit. Inv. 1952–401.

DOMESTIC CLOCKS

110. 16TH-CENTURY CHAMBER CLOCK. From the Percy Webster Collection.

This is a typical example of a weight-driven Gothic chamber clock. It was constructed before the pendulum was applied to clockwork, and its timekeeping is controlled by a "foliot" balance, which consists of a bar carrying adjustable weights which is pushed first in one direction and then in the other by a verge and crown wheel escapement.

The rate of a clock governed by this mechanism depends largely upon the magnitude of the driving weight and the amount of friction in the wheelwork, and the timekeeping is consequently poor compared with that of a clock controlled by a pendulum.

Only one hand is provided—an hour-hand. Minute-hands were not generally added to clocks until the advent of the pendulum had improved their timekeeping sufficiently to make the indications of such a hand of some value.

The clock strikes the hours, the bell-hammer delivering the blow by its own weight, and is also provided with an alarm. Inv. 1954–184, Photos 937/54, 938/54.

111. 16TH-CENTURY DOMESTIC CLOCK. Presented by W. E. Miller, Esq., F.S.A.

This is a typical example of the weight-driven domestic clocks of the period. It is signed, on one of the lowest bars of the frame, VA. [*sic*] L., the initials of the Swiss makers Ulrich and Andreas Liechty of Winterthur, and dated 1596. The foliot balance, the "spire" of the clock and the dial and hand are probably not original, but made in England in the 17th century; clocks by this maker usually had originally a wheel, not a foliot balance.

Like the adjacent larger clock (Catalogue No. 110), this one has a single hour-hand only. It strikes the hours, and formerly had a mechanism for showing the phases of the moon.
Inv. 1932–441, Photos 6023, 6024, 6025.

112. ENGLISH IRON LANTERN CLOCK. From the Percy Webster Collection. Made by John Holloway at Lavington.

The typical English lantern clock of the 17th century was made mainly of brass, but this example, which is dated 1611 on the bottom plate, is made wholly of iron with the exception of the chapter ring and hand, which have probably been renewed.

The clock is thus of special interest as being a transitional type between the German iron Gothic clock of the 16th century and the English brass lantern clock.

The train is almost identical with that of the later Knifton lantern clock of about 1650 exhibited nearby (Catalogue No. 113). Inv. 1954–579, Photos 1/55, 2/55, 3/55.

113. LANTERN CLOCK. Made by Thomas Knifton at the Cross Keys, Lothbury.

The lantern or birdcage clock was the earliest type of clock to be made in any numbers in England, and the type persisted throughout most of the 17th century. The present example, made about 1650, has a verge escapement and retains its wheel balance; later clocks, made after Huygens' pendulum invention of 1657, usually had their timekeeping controlled by a short pendulum, while many of the earliest clocks were converted to employ one, owing to the improvement in timekeeping thereby attained.

The present Knifton clock has a single hour-hand, and the chapter ring is divided into hours and quarters; the striking train is of the usual locking-plate type, and strikes the hours. Inv. 1951–30, Photos 377/51, 378/51, 379/51.

114. ITALIAN COPPER-GILT CHAMBER CLOCK. From the Percy Webster Collection.

This pendulum clock is signed "Camerini, An Dni 1656"; it has going and striking trains and probably had an alarm formerly.

1656 was the year of Huygens' pendulum invention which he did not, however, fully publish until 1658, and it is possible that this clock anticipates Huygens' invention, as it shows no signs of conversion from a foliot balance. Inv. 1954–185, Photo 934/54.

115. 17TH-CENTURY WOODEN CLOCK. Presented by W. E. Miller, Esq., F.S.A.

This domestic clock, probably made at Davos, in Switzerland, is dated 1669 and has a verge escapement of the foliot type with a balance wheel, which has no balance spring.

The framework, wheels, pinions and arbors are made of wood, and the great wheels of the going and striking trains have wooden pivots. The other wheels have steel pivots which are formed of wire passing through the arbors and run in brass bushes in the frames.

The escapement wheel is of wood with inclined projecting iron teeth which engage with an iron verge. Regulation would be effected by increasing or decreasing the driving weight according to whether the clock was losing or gaining.

There are two hands moving over separate dials. The lower hand moves with the great wheel arbor and rotates once an hour, its dial being divided to indicate quarter hours, while the upper hand indicates hours. Inside the upper dial there is an alarm plate with holes into one of which a peg was inserted to actuate the alarm.

The striking mechanism is of the locking plate type and there is no "warning" arrangement. Inv. 1928–1054.

116. WOODEN FOLIOT TIMEPIECE. Lent by H. Baines, Esq., D.Sc.

Timepieces and clocks of this type have been made in the Black Forest area of Germany since about the middle of the 17th century; the date "1640" inscribed on this example relates to this fact and does not necessarily indicate that the timepiece itself was made at this date.

The earliest Black Forest clocks were almost entirely hand-made in the homes of the craftsmen: later examples are factory made and mass-produced.

The timekeeping is governed by a foliot balance driven by a verge and crown-wheel; in this example one arm of the foliot is broken off and the small weights which should hang from the notches on the foliot are missing. Inv. 1951–266.

117. DRAWING OF GALILEO'S ESCAPEMENT. Presented by The Royal Institute of "Studii Superiori," Florence.

This is a copy of a drawing representing Galileo's proposed method of applying the pendulum to clocks.

Following his observations in 1582 of the fundamental property of a pendulum it was possible to measure intervals of time by counting the vibrations of a pendulum, and in 1637 Galileo described a device by means of which the pendulum was made to propel a train of wheels, which automatically recorded the number of vibrations. It was, however, necessary to maintain the pendulum in vibration by occasional external impulses.

In 1641, when he was blind, he conceived the idea of adapting the pendulum to the purpose of controlling clocks driven by weights or springs, and he discussed the question with his son, Vincenzo. They decided upon the method which is represented in this drawing, but Galileo died soon afterwards and it was not until 1649 that Vincenzo arranged to have the mechanism actually constructed.

Writing in 1659 Viviani, a pupil of Galileo, stated that he had seen the mechanism in operation and that Vincenzo was engaged on the work of constructing a complete clock with this escapement at the time of his death in 1649.

A working model is shown adjacently (see Catalogue No. 118).

[See "Science Conferences, 1876"; Physics, pp. 117–122.] Inv. 1876–70.

118. GALILEO'S ESCAPEMENT.

This model, made in 1883, illustrates the mechanism devised by Galileo about 1641 for employing a pendulum to control a clock in place of the "foliot" balances then used.

The escape wheel has 12 teeth which are locked by a hinged detent, and also 12 projecting pins which engage with an impulse pallet mounted on the pendulum. The latter also carries an unlocking pallet which engages with the detent.

Towards the end of the pendulum's swing to the left the detent is raised and the wheel consequently unlocked. The wheel moves until one of the pins engages with the impulse pallet and the wheel is then made to recoil until the pendulum comes to rest. The pendulum receives an impulse during the greater part of the next swing, including the whole of the first half of the swing, until the detent falls into its locking position again.

The interference with the pendulum at the end of its swing to the left is especially undesirable for the purpose of accurate timekeeping. Inv. 1883–29, Photos 96, 290/37.

119. RECONSTRUCTION OF HUYGENS' PENDULUM CLOCK. Made by Messrs. J. Morrison and Sons, London, N.1.

Though Galileo was the first to utilise a pendulum for measuring time, it is uncertain whether he succeeded in applying it to clock mechanism, and it was Christiaan Huygens who in 1658 first fully described a pendulum clock which he had designed. In 1673 he published a treatise entitled "Horologium Oscillatorium" in which the construction of an improved pendulum clock was described in detail; the clock exhibited was constructed in 1927 from this design.

Huygens worked out in detail the theoretical motion of a pendulum, and showed that the period of its swing was not quite independent of the arc of swing, but that it could be made so if the pendulum were suspended by means of a pair of cords slung between two

cheeks of metal shaped in the form of a cycloid; the clock exhibited embodies this construction. The pendulum bob takes the form of a bent elongated cylinder with pointed ends, in order to reduce air resistance.

A verge escapement is employed, and the pallet axis carries a bent "crutch" which embraces the pendulum rod.

The driving weight drives the clock through the agency of an endless cord arrangement invented by Huygens; the advantage of this method is that the driving force remains operative during the process of winding.

The endless cord driving arrangement has been widely employed ever since Huygens' time, but the use of cycloidal cheeks was soon discontinued, as in practice they were found to give rise to a good deal of trouble which more than offset their theoretical advantages.

Inv. 1927–1981, Photo 8229.

120. FRIESLAND CLOCK. Lent by L. N. Parker, Esq.

This is an early 18th-century Dutch clock of the hood type and is controlled by a pendulum in combination with a verge escapement.

The crown escape wheel is mounted on a horizontal axis and the pallets are on a vertical axis which carries a long light arm engaging with a loop in the pendulum.

One weight, which is not encased, drives both the going and the striking trains. The latter is of the locking-plate type but there is no "warning." Half hours are indicated by a single stroke and on the same bell as the hours.

An alarm mechanism is provided and is adjusted by a pointer which is mounted on the front of the hour hand.

The movement is enclosed and is mounted on a bracket which projects from a back board surmounted by a hood. This arrangement may be regarded as an intermediate development between the old brass-cased lantern clock and the later grandfather clock, although examples continued to be made long after the introduction of the latter.

There is an hour hand only, although minute hands had been used in earlier clocks.

Inv. 1925–679, Photos 548/37, 385/48, 386/48.

121. LANTERN CLOCK. Made by Edward Webb, Chewstoke, in 1688. Presented by Dr. M. Gepp.

The lantern or bird-cage clock was the first type of domestic clock to be used to any considerable extent and it appears to have been introduced about the end of the 16th century. The movement was enclosed in a brass case surmounted by a bell, and the clock was mounted on a bracket and driven by weights.

Before the application of the pendulum about 1660 a verge escapement with a balance wheel without a balance spring was employed in clocks of this type, but after that date a verge escapement with a short pendulum, known as a "bob" pendulum, was used, as in this example.

The framing consists of two horizontal plates connected by four corner posts, and there are vertical bars which provide bearings for the pivots of the wheel trains. The striking train is mounted separately behind the going train and not by the side of it as in a modern clock. A locking-plate striking mechanism is employed which includes a warning arrangement. There is only one hand, an hour hand, but the hour divisions of the dial are divided into four parts. The going and striking trains are driven by the same weight by means of an endless cord arrangement.

A characteristic feature of lantern clocks is the ornamentation, by brass "frets," of the tops of the front and sides.

Inv. 1928–722, Photo 7529.

122. LANTERN ALARM TIMEPIECE.

This is signed "Thomas Knifton at the Cross Keys, Lothbury." It has a verge escapement and short "bob" pendulum, and is provided with an alarm.

The chapter-ring is divided into hours and quarters, and there is an hour-hand only.

Knifton was free of the Clockmakers' Company from 1640 to 1662.

Inv. 1951–217, Photo 1155/54.

123. LANTERN CLOCK. Made by John Drury, London. Presented by J. K. Glenn Sarjeant, Esq., and Mrs. E. J. Kempson.

This clock, made about 1700, illustrates a transitional stage between the typical brass lantern clock of the 17th century and the "grandfather" clock of the 18th century. It is fitted with the anchor escapement, introduced about 1670, which requires a much smaller arc of swing than its predecessor, the verge, and so a longer pendulum, giving better control of the timekeeping, can therefore be employed.

The lantern clock was designed for mounting on a bracket projecting from a wall, but with the introduction of the anchor escapement and long pendulum it soon gave way to the

"grandfather" clock in which pendulum and weights were enclosed in a long wooden case resting upon the floor.

The clock exhibited has only one hand, although at this period minute-hands were becoming fairly common. It is fitted with the "rack" type of striking mechanism.

Inv. 1934–652, Photo 7531.

124. MOVEMENT OF EARLY EIGHTEENTH-CENTURY "GRANDFATHER" CLOCK. Made by T. Dicker, Silchester.

This is the movement of an early 18th-century long-case or "grandfather" clock, and illustrates the last stage in the transition from the "lantern" type of clock.

It is driven by a suspended weight and is controlled by means of a long seconds pendulum through the medium of an anchor escapement. It is fitted with a locking-plate striking mechanism and possesses only a single hand, moving over a scale of hours divided into quarters.

Inv. 1935–264.

125. EIGHT-DAY CLOCK. Made by John Harrison. Presented by G. Empringham, Esq.

This was made at Barrow, Lincolnshire, in 1715. With the exception of the escape wheel, the wheels and pinions are of wood, as in other early clocks by Harrison, who, although the winner of the Government award of £20,000 for the invention of his chronometer, was originally trained as a carpenter.

Each wheel is built up of oak in three layers, the teeth being cut in the middle layer, which is in four segments fastened together by two outside circular layers extending to the bottoms of the teeth. The pinions and arbors are of boxwood with steel pivots passing through their entire lengths and running in brass bushes in the frame, which is of oak.

The day of the month is shown through a hole in the dial by means of a numbered disc, the rim of which carries 31 pins and is moved once a day by a pin on a wheel which is driven by a pinion on the arbor of the striking barrel.

A cranked key is employed for winding the driving weights and it is provided with a pinion which gears with wheels on the caps of the barrels. Normally, the holes in the bottom corners of the dial through which the key is passed are covered by removable spandrel ornaments. An ordinary recoil anchor escapement is used and the striking mechanism is of the locking plate type.

The pendulum and the case are not the originals.

Inv. 1884–80, Photos 536, 535, 3329.

REGULATORS

126. REGULATOR. Made by Benjamin Vulliamy.

This was made for King George III and was formerly the principal timekeeper in His Majesty's private observatory which was established at Kew in 1769. It is fitted with the "Grasshopper" escapement invented by John Harrison, in which the escape wheel teeth do not move along the faces of the pallets. This eliminates friction and avoids the necessity of lubrication. Another anti-friction device employed is the extensive use of friction wheels for carrying the bearings of the wheel train.

In the escapement there are two pallets, of hard wood, mounted on the ends of separate arms which are hinged in a frame secured to the pendulum crutch. As shown in the accompanying diagram, a tooth of the wheel engages with the left-hand pallet and pressing against it urges the pallet upward and consequently impels the pendulum to the left. During this swing the tooth remains in contact with the pallet, and relative motion of the latter is prevented by the pressure of the tooth, and the flat spring, A, which engages with the tail of the pallet arm, is consequently strained. At the end of the swing the other pallet intercepts the path of the tooth, B, and engaging with it causes the wheel to recoil a little. This recoil releases the left-hand pallet from engagement with the escape wheel tooth and the pallet consequently jumps away from the wheel under the action of the spring, A, the extent of the motion being limited by another flat spring. A similar process of operations is now repeated with the wheel engaging with the right-hand pallet as the pendulum makes its return swing.

This escapement has a large arc of vibration and the pendulum receives an almost continuous impulse throughout each swing.

Each pivot of the wheel train rests upon a pair of friction wheels one of which is set higher than the other according to the direction in which the pressure of the pivot acts. The friction wheels supporting the pivots of the pallet frame are, however, arranged symmetrically. The great wheel is raised from its friction wheel bearings during winding.

A sun-and-planet maintaining power mechanism is employed to keep the clock going during winding and a gridiron pendulum is employed to obtain compensation for variations of temperature.

Inv. 1884–79, Photos 3330, 533, 1234/54, 1235/54.

127. REGULATOR. Presented by Lord Riddell.

This regulator was made in 1832 by the well-known maker B. L. Vulliamy, the son of Benjamin Vulliamy, and is a good example of the most accurate kind of clock of the period. A clock of this type is capable of keeping time to an accuracy of approximately one-tenth of a second per day under good conditions.

The escapement is Graham's dead-beat, having jewelled and long leverage pallets. The wheels and frames are of hard hammered brass, with screwed-in bushed bearings to all pivots and adjustable end bearings. The pinions are of high numbers, viz.:—20, 24 and 22 teeth respectively, and are made of highly glossed hardened steel; the wheels also are of high numbers, viz.:—240, 180, 176 and 30 teeth respectively. The object of all these refinements is, of course, to reduce to a minimum the friction in the train of wheels.

The pendulum is fitted with Graham's mercurial compensation for change of temperature, the downward expansion of the pendulum rod in heat being compensated by the greater upward expansion of the mercury. This was the most accurate temperature compensation available at the period.

The clock goes for eight days and is fitted with Harrison's maintaining power to keep it going while being wound. Inv. 1935–44.

128. REGULATOR WITH GRAVITY ESCAPEMENT. Lent by R. Bloxam, Esq.

In a gravity escapement the wheel train does not act directly on the pendulum, but is arranged to lift gravity arms which, when falling, give impulses to the pendulum. Such impulses are constant and independent of any variations which may occur in the power transmitted by the wheel train. The gravity escapement shown was patented by J. M. Bloxam about 1850.

There are two gravity arms which are separately pivoted on the same axis, and the escape wheel consists of an inner wheel or pinion of nine teeth, which lift the arms by engaging with pallets in the latter, and an outer wheel of nine teeth which effect the locking by engaging with detents on the arms. The arms also carry projections which engage with the pendulum.

When the pendulum is at the end of a swing, say to the right, the wheel is locked by engagement with the left-hand gravity arm. The right-hand arm rests against the pendulum which it follows during the next swing to the left until its pallet comes into contact with a tooth of the pinion. The pendulum next engages with the left-hand arm and so moves it that the outer wheel is unlocked. The wheel then moves forward until locked by the right-hand detent while the pinion lifts the right-hand arm, causing it to jump away from the pendulum. The amount by which the arm is lifted represents the impulse which it gives to the pendulum during the next swing to the left. A similar action also takes place during a swing to the right.

The wheel train is carefully made and employs pinions of 18 teeth. The main wheel rotates once a day and carries a graduated ring for indicating the hours; the minutes are indicated by three pointers mounted on the second wheel, which rotates once in three hours, and the seconds by three pointers on the fourth wheel which makes one revolution in three minutes.

A compensation pendulum, consisting of a steel rod with a cast iron jar containing mercury, is employed.

[See Memoirs of the Royal Astronomical Society, Vol. 22.] Inv. 1879–32, Photo 3444.

129. RIEFLER REGULATOR. Bequeathed by E. T. Cottingham, Esq.

This regulator was made by Messrs. T. Mercer from designs by the late E. T. Cottingham. It employs the escapement patented by Riefler of Munich in 1889, but embodies improvements on Riefler's original design.

The pendulum itself swings freely, and impulses are imparted to it every second from the escapement through its suspension spring. The regulator is driven by a small weighted arm re-set electrically at intervals of about half a minute.

The pendulum swings in an airtight cylinder in which the air pressure can be maintained constant. Inv. 1940–15.

130. REGULATOR WITH GRAVITY ESCAPEMENT. Made and presented by W. G. Schoof, Esq.

This has a gravity escapement of a form which was proposed by Schoof in 1890.

The impulse is given to the pendulum by two separate gravity arms. These arms carry pallets and have pins at their lower ends which are situated one on each side of the pendulum. As the pendulum swings to the right it carries the right-hand gravity arm with it and the wheel is unlocked and an impulse given to the gravity arm in a manner similar to the action of a Graham dead-beat escapement. The amount by which the arm is thus raised independently of the action of the pendulum determines the energy which the arm gives as impulse to the pendulum during the next swing to the left.

The clock goes eight days for each winding and has a seconds pendulum. The example shown has an escape wheel with 90 club-shaped teeth, but Schoof proposed the construction of a giant clock with a wheel of 3,600 teeth and a six-seconds pendulum about 120 ft. long. Inv. 1900–91.

131. RUDD'S FREE PENDULUM CLOCK. Presented by F. Hope-Jones, Esq.

This experimental clock, constructed by its inventor, R. J. Rudd of Croydon, in 1899, was the first to embody the principle of the Free Pendulum and Slave Clock. Rudd's actual mechanisms are very delicate and difficult to keep in adjustment and have therefore been superseded, but his idea has led to the modern Shortt clock (see Catalogue No. 392), whose accuracy over long periods exceeds that of any other mechanical timekeeper.

The best mechanical timekeeper known is a pendulum swinging freely under gravity, but in order to convert such a pendulum into a practical clock the pendulum must be sustained in motion so that its oscillations do not die down, and the swings must be counted. In ordinary clocks the sustaining and counting functions are both carried out by the escapement and clock mechanism, but the free motion of the pendulum is considerably interfered with thereby.

In the Rudd clock the two functions are carried out by a subsidiary or "slave" clock. This clock gives an impulse every minute to the free pendulum and the rate of the slave clock is automatically regulated by the free pendulum so that the impulses always arrive at the correct moment at the middle of a swing. If an impulse from the slave arrives too early the regulator of the slave clock is set "slow" for the ensuing minute, if too late it is set "fast." The slave soon settles down so that its rate is equal to that of the free pendulum, and any subsequent variations of its rate are automatically corrected.

The impulse to the free pendulum is imparted by a system mounted on the top of the slave clock. This will be referred to as "the impulse system"; it consists of an arbor carrying (1) a pair of arms which impart the impulse to the free pendulum; (2) a pair of long arms one of which is normally locked against a grooved arbor, but is freed once a minute when this arbor is slightly rotated; (3) two pairs of short arms which after the impulse is over reset the releasing mechanism in readiness for the next impulse a minute later; (4) a pulley over which passes a loaded chain.

At the end of every minute the long arm is released, the weight falls and turns the pulley, and the blow is imparted to the pendulum, the arbor of the impulse system making a half revolution. The release of the long arm is accomplished in three stages, the first and second of which are comparatively roughly timed. The final release, however, occurs when a pin on an arm falls through a slot in a small plate carried by the pendulum, and accordingly always takes place at exactly the same phase of the pendulum swing; this point is important in connection with the regulating mechanism described below. The energy of the impulse is supplied by the falling weight, which is slowly and continuously wound up between impulses by means of a Huygens endless chain.

The Automatic Regulator. As described above, the slave clock is automatically regulated at each impulse.

The suspension spring of its pendulum hangs between two pins which are mounted on a movable regulator arm. The effective length of the pendulum and hence the rate of the clock thus depends on the position of this arm, and it is this which is adjusted during an impulse.

The slave pendulum carries a curved arm or "snail" against which a "feeler" pin is pressed during an impulse, the pin being released after the impulse arm has delivered its blow to the free pendulum. If the slave clock is early, the impulse arm is held up for a small fraction of a second as it rests against the free pendulum, the release of the "feeler" pin is accordingly delayed, and the pin is therefore at a higher position when released. By means of a connecting system the regulator arm is also set high during the ensuing minute, and the slave clock therefore runs slower. Conversely, if the slave clock is late the regulator arm is set low and the clock therefore runs faster.

The position of the regulator arm can easily be studied, as it carries a pointer moving over a roughly divided scale. Inv. 1930–665, Photos 8106, 8105, 8108, 8134.

132. SIDEREAL AND MEAN TIME CLOCK.

This clock was designed by Joseph Vines in 1836 and made by Walsh of Newbury. It has two dials, showing sidereal and mean solar time respectively. The two trains of wheels are connected by gearing and there is only one escapement the pendulum of which beats sidereal seconds.

The connection between the two trains consists of a wheel of 32 teeth, on the escape wheel arbor of the sidereal train, gearing with a wheel of 247 teeth which is on the same axis as another wheel with 331 teeth. The latter gears with a wheel of 43 teeth on the same axis as the seconds hands of the mean time train. The error involved with this gearing is about ·0005 second a day.

To afford a ready means of comparing the sidereal and mean time seconds, a supplementary moving dial is arranged inside the mean time seconds dial and this moving dial is

made to rotate backward at such a rate that the same hand indicates mean time seconds on the outer dial and sidereal seconds on the moving inner dial.

A special form of gravity escapement is employed, which has two escape wheels each of 30 teeth on the same axis. The larger of these engages with a locking pallet and the smaller with a jewel pin mounted on a bell crank lever which effects the impulse. The crutch is weighted and engages with only the left-hand side of the pendulum, and the arrangements are such that at the end of each swing to the right the crutch is lifted backward from the pendulum, the amount by which it is raised forming the impulse, which is given to the pendulum during the next swing to the right. As the wheel train is released at the end of each alternate swing the hands move through intervals of two seconds at a time. The pendulum is of the Harrison compensation form with five steel and four brass rods.

In addition to hands indicating sidereal hours, minutes and seconds, the sidereal dial carries a hand which bears a representation of the sun and indicates the mean solar hours. There is also a moon hand which in a lunar month makes one rotation less than the mean solar hand, and thus indicates the position of the moon with respect to the sun. In this hand there is a hole with a white piece behind to represent the moon, while a black disc, which is mounted on a lever actuated by a cam, moves in front of the white piece and thus indicates the phases of the moon. Inv. 1906–56, Photo 66/54, 67/54.

SPECIAL DIAL

133. 24-HOUR DIAL. Made by The Synchronome Co., Ltd. Presented by F. Hope-Jones, Esq.

For some purposes it is convenient to reckon the day in 24 hours starting from midnight, and when this system is adopted a dial similar to the one exhibited is employed for clocks and watches.

In order to indicate the time uniquely it would be necessary to employ a dial having 24 hours in a single ring, and to alter the clock mechanism so as to make the hour-hand rotate once in 24 hours instead of in 12 hours. In order to avoid such alteration of mechanism the present type of dial is employed, so that ordinary clocks can be made to show 24 hour time with very little modification. There is no ambiguity with this type of dial for in all practical cases an observer looking at a clock knows whether the time is a.m. or p.m. and hence is able to read off the time on the appropriate ring of figures. Inv. 1931–279.

ESCAPEMENTS

134. RECOIL ESCAPEMENT.

This model shows the anchor or recoil escapement which was invented by William Clement or Robert Hooke about 1670.

The escape wheel teeth engage alternately with two inclined faces or pallets, which form part of an anchor-shaped piece, and during such engagement a tooth tends to move a pallet sideways until the tooth escapes past the edge of the pallet face. The wheel then turns a little until stopped by the engagement of another tooth with the opposite pallet, and as the anchor continues to move under the action of the pendulum the wheel is made to recoil until the pendulum comes to rest. This form of escapement is the one which is most extensively employed for clocks, other than precision clocks.

The model is so designed that the actions can be projected on a screen.

Inv. 1883–54, Photo 157/48.

135. DEAD-BEAT ESCAPEMENT.

This model shows the dead-beat escapement which was invented by George Graham about 1715.

In this escapement the locking faces of the pallets form parts of circles with the pallet staff as centre, and the escape wheel consequently remains at rest except when engaging with the inclined impulse faces of the pallets. This form of escapement is the one which has been most generally used for weight driven clocks of precision.

The model is so designed that the action can be projected on a screen.

Inv. 1883–64, Photo 151/48.

SET OF NINE MODELS SHOWING ESCAPEMENTS EMPLOYED IN LONG-CASE CLOCKS, BRACKET CLOCKS AND REGULATORS. Lent by Messrs. Hobson Brothers, Hove.

136. EARLY TYPE OF VERGE ESCAPEMENT. Inv. 1952–345, Photo 461/53.

137. TIC-TAC TYPE ESCAPEMENT. Inv. 1952–346, Photo 462/53.

138. ANCHOR ESCAPEMENT FOR LONG-CASE CLOCKS.
Inv. 1952–347, Photo 468/53.

139. LATE VERGE ESCAPEMENT FOR BRACKET CLOCKS.
Inv. 1952–348, Photo 464/53.

140. ANCHOR ESCAPEMENT FOR BRACKET CLOCKS.
Inv. 1952–344, Photo 463/53.

141. DEAD-BEAT ESCAPEMENT AS INVENTED BY GEORGE GRAHAM.
Inv. 1952–341, Photo 465/53.

142. HALF DEAD-BEAT ESCAPEMENT. Inv. 1952–342, Photo 466/53.

143. DEAD-BEAT REGULATOR ESCAPEMENT. Inv. 1952–343, Photo 469/53.

144. ANCHOR ESCAPEMENT WITH LAYOUT SIMILAR TO THAT OF A GRAHAM DEAD-BEAT ESCAPEMENT. Inv. 1952–349, Photo 467/53.

145. EIGHT-DAY PENDULUM CLOCK WITH MAGNETIC ESCAPEMENT. Presented by Horstmann Clifford Magnetics, Ltd., Newbridge Works, Bath.

The clock here exhibited represents one form of the magnetic escapement for pendulum clocks invented by C. F. Clifford and patented by him in 1947. In this escapement there is no actual mechanical contact between the escape wheel and the pendulum, the impulse to the pendulum being transmitted by magnetic forces. Friction between the escape wheel and pallets is thus eliminated, and although there are hysteresis and eddy-current losses in the magnetic elements these are so much less than the frictional losses in an anchor or dead-beat escapement that the mechanical efficiency is increased by a factor of approximately three, so that a given spring will drive a clock three times as long if the gearing is rearranged accordingly. The clock is almost completely silent and the escapement of course requires no oil.

In the example shown, the magnet is of 15 per cent. cobalt steel and takes the form of a figure-of-eight, the poles facing each other at the waist; the escape wheel is of Mumetal. The magnetic circuit remains almost closed throughout the period of the pendulum's oscillation. The escape wheel is so shaped that an approximately sinusoidal impulse is given to the pendulum, with a maximum at the centre of the swing in each direction. As with a mechanical escapement, the escape wheel moves through the pitch of one tooth for each double swing of the pendulum.

Two guard pallets are provided; these normally move clear of the star-wheel, but one or other will engage with it and prevent the wheel train from "running away" in the event of the magnet poles moving too far away from the escape wheel to control it, e.g., if the clock is lifted and tilted.

Examples of the magnet and star-wheel can be seen mounted on a board adjacently.
[See British Patent Specification No. 596,216.] Inv. 1949–114.

146. EIGHT-DAY TIMEPIECE MOVEMENT WITH MAGNETIC ESCAPEMENT. Made by Rotherham and Sons, Ltd.

This movement is similar in principle to the adjacent one (Catalogue No. 145), and represents a different form of the magnetic escapement invented and patented by C. F. Clifford in 1947.

The permanent magnet, mounted on the pendulum, is in the form of a circle with two small internally projecting pole-pieces, while the escape wheel is in the form of a crinkled sine-wave. As in the adjacent example, the magnetic circuit remains almost closed throughout the period of the pendulum's oscillation, and the escape wheel is so shaped that an approximately sinusoidal impulse is given to the pendulum, with a maximum at the centre of the swing in each direction. As with a mechanical escapement, the escape wheel moves through the pitch of one tooth for each double swing of the pendulum.

Two guard pallets are provided to prevent the escape wheel from running freely if the clock is tilted through a large angle.

[See British Patent Specification No. 596,216; also *Mond Nickel Bulletin*, vol. 21, p. 138 (1948).] Inv. 1951–59.

IV. WATCHES AND SPRING-DRIVEN CLOCKS

THE INVENTION of spring-drive, which made portable clocks and watches possible, was made towards the end of the 15th century, and the first watches—portable timekeepers small enough to be carried about on the person—were made in Nuremberg shortly after 1500. In the earliest spring clocks and watches the varying spring pull was compensated by a very rough device known as a stackfreed, but about 1525 a much better device termed a fusee was applied for this purpose.

The invention of the balance-spring about 1675 gave a great improvement in timekeeping, and the subsequent improvements in watches have consisted mainly in the invention of better escapements which leave the oscillating balance as free as possible.

The spring-driven clocks in the Science Museum Collection include table and bracket clocks and two "world clocks".

The watches are grouped mainly according to the type of escapement which they employ, but other groups show stop-watches, chronometer watches, repeaters and musical repeaters, winding and regulating and other special mechanisms.

The Collection also includes large-scale models of watch escapements, and models and examples of various other mechanisms associated with watches and spring-driven clocks.

TABLE CLOCKS

147. 16TH-CENTURY GERMAN ALARM TABLE TIMEPIECE.

This timepiece dates from about 1550. Apart from the fusee, the movement is wholly of iron. The balance is in the form of a dumb-bell.

The outer ring of hour-figures runs from 1 to 24, the inner ring from 1 to 12 twice over.

The alarm can be set by rotating the inner alarm disc, which is numbered from 1 to 24.

Inv. 1954–186, Photos 935/54, 936/54.

148. DRUM CALENDAR TIMEPIECE WITH DETACHABLE ALARM.

This timepiece dates from about 1600, and has a verge escapement with a balance-wheel: the balance-spring is a later addition.

It is provided with an hour-hand and a shorter hand which indicates the day of the month on a scale reading from 1 to 31. There is no special provision for the shorter months.

The separate alarm mechanism is clipped on to the top of the clock and the alarm lever is tripped by the hour-hand. Inv. 1953–379, Photo 939/54.

149. 17TH-CENTURY ENGLISH TABLE-CLOCK.

English table-clocks of this period are far from common; this example was made by David Bouquet, who was admitted to the Clockmakers' Company in 1632 and died in 1665, and is signed "David Bouquet à Londres."

It is a spring-driven striking clock, and has a verge escapement without balance-spring. It is fitted with a single hour-hand, and has touch-pins for finding the time by night.

The frame and wheels are of brass. Inv. 1953–48, Photos 808/52, 809/52.

150. ASTRONOMICAL TABLE TIMEPIECE. Presented by W. E. Miller, Esq., F.S.A.

N. Vallin, the maker of this clock, was one of the few English clock-makers of the Elizabethan period. The clock shows the hour of the day (on a circle of twice twelve hours), the date, the positions of the sun and moon in the zodiac, the age and phase of the moon,

the difference between solar and lunar times, and the time of high tide in London. The timekeeping part of the clock movement has been partly renewed and part of it is missing, but the gearing for the dial is complete.

The hour hand rotates once in 24 hours (solar time); the date indicator, to which the sun pointer is attached, once in 365 days; and the moon pointer makes one revolution relative to the stars in 27·43 days (192 divided by 7). The correct figure is 27·32 days, so that the error in the moon's age will accumulate at the rate of about 1½ days per year. There is no allowance for leap-year, so that the sun pointer will err by one day every four years. Inv. 1938–429, Photo 642/51.

151. 17TH-CENTURY OCTAGONAL TIMEPIECE. Bequeathed by Mrs. V. E. F. Becker.

This timepiece, the movement of which is inscribed "David Weber, Aug." is presumably of Augsburg make, and dates from the early 17th century. It is a typical example of a table-clock of the period.

The going train is driven by a mainspring through a fusee and chain, and the timekeeping is controlled by a balance-wheel without balance-spring, through a verge escapement. The clock has a single hand, showing the hours, and is fitted with an alarm which can be set by rotating the central, inner dial. Inv. 1942–57, Photos 57/50, 62/50.

152. 17TH-CENTURY TABLE-CLOCK. Presented by H.M. King George VI.

This clock dates from about the middle of the 17th century; its movement is inscribed "Geo. Cri. Lucenberg er Augspurg," a maker who died in 1660.

The timekeeping is controlled by a balance-wheel without balance-spring, and a bristle regulator is fitted. Two short bristles are mounted on a pivoted arm and engage with the diametral strip of the balance; the extent of the engagement depends upon the position of the arm which carries the bristles, and so a rather crude method of regulation is achieved.

The going train of the clock is driven through a fusee with chain, while the striking train has a going-barrel. A number of wheels in both trains appear to have been renewed.

The clock is fitted with a single hour-hand and strikes the hours.

Inv. 1949–232, Photos 34/50, 35/50, 36/50.

153. 17TH-CENTURY TABLE-CLOCK (see Plate V).

Clocks of this general type were being made at Augsburg and other centres in South Germany during the late 16th and early 17th centuries. The example exhibited here bears no maker's name or date, but was made probably about 1630.

The main part of the movement is in its original condition, but the pendulum was probably added during the second half of the 17th century. Many of the gear trains for driving the astronomical dial pointers are missing.

The indications of the dials are as follows:

Main dial on front of clock. The two long double-ended pointers show mean solar time and lunar time, on the outermost ring of 2 × 12 hours. The phase of the moon is shown by the circular opening in the disc carrying the moon-pointers, while the moon's age can be read off from the position of the edge of the moon-pointer on the circular scale on the disc carrying the sun-pointer. The remainder of this dial is an astrolabe, and shows the position (altitude and azimuth) in the heavens of the sun, moon and a number of selected stars shown by the small pointers on the rotating fret or "rete."

The lower left-hand dial gives the Dominical Letter (or Letters) for the year, and also the number of the year in the major or solar cycle.

The dial on the left side of the clock, reading from 1 to 4, shows which quarter has chimed.

The dial on the right side of the clock shows which hour has last struck, on two circles reading 1 to 12 and 1 to 24 respectively.

The main dial on the back of the clock has been mutilated, but originally showed minutes, hours on the 2 × 12 system, and also Italian hours.

The two lower dials on the back of the clock show the day of the week and the position of the sun in the zodiac respectively. Inv. 1952–312, Photos 695/50 to 698/50.

154. TIMEPIECE WITH "CROSS-BEAT" ESCAPEMENT. Lent by Dr. Hans von Bertele.

The "cross-beat" escapement was used by Jobst Burgi and his school between about 1580 and 1660 in place of the more usual verge escapement of this period.

The "cross-beat" employs a flat escape wheel, and the two pallets are mounted on separate parallel arbors which are geared together in opposition. Each arbor carries a balance, and in many "cross-beats" the balance arms are thin and pliable, giving a slight "balance-spring" effect.

The timepiece exhibited, by Francisco Schwartz of Brussels, dates from about 1630.

The dial, hands, escape wheel and pallets and cross-beat levers were missing and have recently been renewed.

The only way to regulate this type of timepiece is by adjusting the tension of the mainspring in its barrel, and special arrangements are provided for this on the back of the timepiece.

[See The Horological Journal, December, 1953, pp. 794–816.] Inv. 1954–469.

155. 17TH-CENTURY TABLE-CLOCK. Bequeathed by Mrs. V. E. F. Becker.

This clock is of later date than the adjacent ones, and probably dates from the late 17th century.

It is provided with both alarm and striking mechanisms, and shows minutes as well as hours upon its dial. The inner, rotating ring on the dial is for setting the alarm.

The timekeeping is controlled by a balance-wheel fitted with a balance-spring, and the going train is driven by a mainspring through a fusee and chain. The alarm and striking trains are driven by separate springs mounted in going barrels.

Inv. 1942–58, Photo 58/50

BRACKET CLOCKS

156. BRACKET CLOCK.

This is signed I. Thuret à Paris, and is the work of Isaac Thuret who made clocks for Huygens while he was in Paris during the period 1665–81. Thuret was clockmaker to Louis XIV, and died in 1700.

The going and striking trains of this clock are driven from the same mainspring, and the pendulum swings between "cheeks" which are not, however, of the correct cycloidal form calculated by Huygens which would make the period of the pendulum independent of its arc of swing.

The locking-plate has been renewed. Inv. 1954–458, Photos 1148/54, 1149/54, 1150/54.

157. BRACKET CLOCK. Lent by H. Baines, Esq., D.Sc.

This clock, by Isaac Papavoine of London, is a typical bracket clock of about 1690.

It strikes the hours and is fitted with a pull-repeater for the quarters. This gives the strike alone for the period between the hour and one-quarter past; a single chime followed by the strike for the period between one-quarter and half-past; a double chime followed by the strike between half-past and a quarter-to the hour; and a triple chime followed by the strike between a quarter-to and the hour itself. At 6.35, for instance, it will give a double chime followed by six strokes on the hour bell.

Both going and striking trains are driven through fusees, and the timekeeping is controlled by a light "bob" pendulum through a verge escapement. The day of the month is shown through an aperture in the upper half of the dial.

The ebonised case is fitted with a "basket" top. Inv. 1951–370.

158. DUTCH BRACKET CLOCK. From the Percy Webster Collection.

Johannes van Ceulen, of the Hague, Holland, the maker of this clock, was one of the first to construct pendulum clocks similar in general to Huygens' pioneer designs of 1658 and 1673. Van Ceulen made his famous "Planetarium" for Huygens in 1681, and died in 1715.

The clock exhibited is one of the type known as "Haagsch Klokje": the same mainspring drives both going and striking trains, and the timekeeping is controlled through a verge escapement by a pendulum which is suspended between "cheeks" as recommended by Huygens, in an attempt to make its time of swing independent of the arc. The cheeks on this clock, however, as on many others of its type, are much too sharply curved to give correct compensation.

The clock has both hour- and minute-hands.

Inv. 1954–580, Photos 1151/54 to 1154/54.

WORLD CLOCKS

159. CHRONOSPHERE.

This consists of a terrestrial globe which is driven by a clock mechanism contained in the base and makes one complete rotation from west to east in 24 hours. With its aid the local mean solar time at any place on the earth's surface can be determined by following a line of longitude from the place in question to the equator and reading off the time upon the hour ring which surrounds the equator.

The globe is mounted upon an axis inclined at $23\frac{1}{2}°$ to the vertical and the sun would therefore lie always in a horizontal plane passing through the centre of the globe.
Inv. 1909–199.

160. THE WILLIS "WORLD CLOCK." Lent by Messrs. J. H. Willis and Co., Norwich.

This clock is specially designed to show the time at any place in the world, and is intended for use by cable companies, wireless operators, news agencies, persons receiving wireless programmes from far distant stations, or in any other connection in which it is necessary to know the time in distant countries.

The dial carrying the hour marks rotates anti-clockwise in the centre of the fixed dial. The fixed dial bears 24 principal radial lines corresponding to the 24 standard time-zones into which the world is divided, and on each of these lines are inscribed in black letters the names of the principal countries belonging to that zone.

The time in each particular zone is read off from the point at which its radial line meets the rotating hour circle. For greater accuracy in reading the minutes a single hand, rotating once an hour, is mounted below, and shows the number of minutes past the standard hour everywhere, the red or reverse end of the hand showing the number of minutes past the hour for the few countries such as India whose time-zone lies half-way between two of the standard zones. A few countries have a standard time differing by a fraction of an hour from standard zone time, and in these cases the small figure adjoining the name shows the number of minutes to be added to or subtracted from the reading of the minute-hand.

An entry in red signifies that during the observance of "summer time" a country is temporarily in the zone indicated by its name in red letters.

The asterisk on the fixed dial shows where the new day begins: all zones from this asterisk around the dial in an anti-clockwise direction to midnight are in the new day, the remainder of the world being still in the old day. Inv. 1935–8.

WATCHES

VERGE ESCAPEMENT

161. DIAGRAM OF VERGE ESCAPEMENT (see Plate VI).

The verge, which is also known as the crown wheel or vertical escapement, is the earliest form of escapement definitely known to have been employed. It was used for controlling clocks as early as the 14th century and was employed in the portable timekeepers, known as table-clocks, which came into use in the 16th century and developed into the pocket watch in the early 17th century.

As shown in the accompanying sketch it consists of a "crown" wheel with pointed teeth which engage with two projections or "pallets" on the axis of the balance wheel. In action a tooth presses against a pallet and imparts an impulse which causes the balance to rotate until the pallet has moved through such an angle that the tooth ceases to engage with it, and the wheel is then free to move until another tooth engages with the second pallet. As the two pallets engage with opposite sides of a diameter of the crown wheel, this tooth is moving in an opposite direction to the second pallet and its first action is to bring the pallet and balance to rest, during which process the wheel recoils a little. An impulse is then imparted to the second pallet and the balance made to rotate in the opposite direction. The successive engagements between the wheel teeth and the pallets result in an oscillating motion being imparted to the balance. This action can be seen in the large example of this escapement included in the turret clock formerly in Dover Castle (Catalogue No. 106), exhibited in this Gallery.

In the earliest pocket watches there was no controlling spring on the balance, but about 1660 Hooke invented the balance spring which made accurate timekeeping possible, and about 1675 Huygens showed how to apply it successfully.

The collection of verge watches shown illustrates various modifications of the arrangements of the movements, the types of watch cases, and the ornamental features of the pillars, plates, and of the cocks, the pieces which carry the upper bearing of the balance. It will be noticed that the extent of ornamentation was considerably reduced towards the end of the 18th century. Inv. 1928–1180.

162. VERGE WATCH, without balance-spring, with bristle regulator for the balance and stackfreed for equalising the pull of the mainspring. German. 16th century. Presented by W. E. Miller, Esq., F.S.A. Inv. 1937–289, Photo 441/37.

163. LATE 16TH-CENTURY GERMAN OVAL WATCH with iron movement and stackfreed controller. Inv. 1954–578.

164. ENGLISH VERGE WATCH of about 1630 by Richard Jackson. Inv. 1954–187, Photos 610/54, 611/54.

165. VERGE WATCH of about 1640 by John Charlton, London. Lent by C. A. Ilbert, Esq. Inv. 1952–329, Photo 380/53.

From the Evan Roberts Collection:

166. VERGE WATCH in triple case, by Dan. Quare, London. No. 4559. About 1700. Inv. 1916–93.

167. VERGE WATCH in silver repoussé pair case, by Thomas Taylor, Holborn. About 1700. Inv. 1916–108.

168. VERGE WATCH in silver inner case, shagreen outer case, by Theo. Fisher, London. No. 2. About 1700. Inv. 1916–97.

169. VERGE WATCH in silver pair case, by Ed. Wrench, Chester. About 1700. About 1916–95.

170. VERGE WATCH in pair case, by T. Tompion and E. Banger. No. 3435. Early 18th century. Inv. 1916–96, Photo 3381.

171. VERGE WATCH, by Thos. Mudge, London. No. 31. 18th century. Inv. 1916–117.

172. VERGE WATCH in silver inner case, by Thos. Dwerrihouse, Garston, with silver plate and cock. No. 166. Hall-mark 1774. Inv. 1916–121.

173. VERGE WATCH, by Geo. Graham, London. Chester hall-marked case. No. 5175. 1779. Inv. 1916–120.

174. VERGE WATCH in pinchbeck repoussé pair case, by Josh Emery, London. No. 797. About 1780. Inv. 1916–116.

175. VERGE WATCH with skeleton plate, by Imison, London. No. 23. Hall-mark 1786. Inv. 1916–109.

176. VERGE WATCH in silver pair case, by Wm. Finch, Halifax, with silver cock. Late 18th century. Inv. 1916–124.

177. VERGE WATCH in silver pair case, by Jos. Dumbill, Prescot. Silver top plate. No. 416. Early 19th century. Inv. 1916–113.

178. VERGE WATCH with three-quarter plate movement, in silver case, by John Weston, London. No. 1842. 1842. Inv. 1916–111.

179. VERGE WATCH in silver octagonal case, by Berthoud, Paris. Late 18th century. Inv. 1916–133.

180. VERGE WATCH in silver case, by Rosé, Soleure, with large balance wheel. Early 19th century. Inv. 1916–130.

From the Bruno Roberts Collection:

181. ENGLISH VERGE WATCH MOVEMENT, by T. Tompion, London, with tulip pillars, pierced and engraved balance cock, and tangent screw arrangement for setting up the mainspring. Late 17th century. Inv. 1920–487.

182. ENGLISH VERGE WATCH MOVEMENT, by Tyler, London, No. 368, with skeleton top plate and pierced barrel cover. 18th century. Inv. 1920–497.

183. ENGLISH VERGE WATCH MOVEMENT, with hare and snail indicator for the regulator, inscribed "Ann Raven." Early 19th century. Inv. 1920–495.

184. ENGLISH VERGE WATCH MOVEMENT, by Geo. Yonge, London, with arrangement for setting the hands from the back and special marking for guidance when winding the spring or setting the hands. About 1800. Inv. 1920–496.

185. DUTCH VERGE WATCH, by John van Ceulen, The Hague. About 1700. Bequeathed by H. Batsford, Esq. Inv. 1953–47.

DEBAUFRE'S ESCAPEMENT

186. DIAGRAM OF DEBAUFRE'S ESCAPEMENT.

This escapement, which was invented by Peter Debaufre about 1700, may be regarded as a modification of the verge escapement in which the recoil of the verge is eliminated.

There are two escape wheels with pointed teeth, mounted on a common axis and situated one on each side of the balance staff, and the latter carries a small pallet piece which is cut away on one side to give an inclined plane impulse surface. In the diagram a tooth of the nearer wheel is shown engaging with this surface and as the tooth moves upward the balance receives an impulse urging it counter-clockwise. When the tooth slips off the impulse face the wheel advances until the next tooth of the further wheel engages with a flat locking face on the bottom of the pallet. On the return swing of the balance this tooth is unlocked and in turn imparts an impulse to the pallet, but as the action is now on the opposite side of the balance staff the impulse impels the balance in a clockwise direction.

The elimination of any recoil is a considerable advantage and dispensed with the necessity of a fusee. In the early part of the 19th century a number of going barrel watches with this escapement were made, more especially at Ormskirk, Lancashire, where it was known as the "club-footed verge."

Some examples of watch movements with this escapement are shown adjacently.

Inv. 1928–1181.

From the Evan Roberts Collection:

187. WATCH with Debaufre type escapement, with two pin wheels, by Thos. Harrison, Liverpool. No. 109. About 1760. Inv. 1916–198.

188. WATCH with going barrel and club-footed verge escapement, by James Ryland, Ormskirk. No. 646. About 1800. Inv. 1916–201.

189. WATCH MOVEMENT with club-footed verge escapement, by Jas. Houghton, Ormskirk. No. 1260. Inv. 1916–281.

From the Bruno Roberts Collection:

190. ENGLISH WATCH MOVEMENT, by Robert Roskell, Liverpool, No. 1896, with club-footed verge escapement. Early 19th century. Inv. 1920–515.

From the Evan Roberts Collection:

191. WATCH, in silver case, by J. S. Magnin, with special escapement. Late 18th century. Inv. 1916–202.

VIRGULE ESCAPEMENT

192. DIAGRAM OF VIRGULE ESCAPEMENT.

This form of escapement is now obsolete, but it was formerly used to a limited extent, especially towards the end of the 18th century. The credit for its invention and development has been claimed for the Abbé Hautefeuille, Caron, Lepine, and Lepaute.

As shown in the diagram the escape wheel has a series of curved teeth at the ends of which are vertical projections. On the axis of the balance wheel there is a hook or comma-shaped piece from which the escapement derived its name, virgule being the French equivalent of comma.

In the small diagram a vertical projection of a tooth is shown imparting an impulse to the hook. When the tooth escapes from the hook, the wheel advances and the next tooth locks against the outside, A, of the hook. During the return swing of the balance wheel, this tooth passes into the small cylindrical cavity shown and in so doing imparts to the

balance a small subsidiary impulse known as the small lift, the main impulse, previously described, given to the hook being the great lift.

An example of a watch movement with this escapement is shown nearby. (Catalogue No. 193.) Inv. 1928–1188.

From the Bruno Roberts Collection:

193. FRENCH CENTRE-SECONDS WATCH MOVEMENT, with virgule escapement, and skeleton upper plate. About 1800. Inv. 1920–512.

WATCHES WITH "PENDULUM" BALANCES

In these watches the rim of the balance-wheel is covered by the cock and a small circular weight is added to the balance arm to produce the appearance of a vibrating pendulum.

From the Evan Roberts Collection:

194. VERGE WATCH, by D. B. D. Neveren, with pendulum balance wheel. Hall-mark 1784. Inv. 1916–207.

195. VERGE WATCH in silver repoussé case, by Pieter Thijmen, Gouda, with pendulum balance wheel. Inv. 1916–204.

196. VERGE WATCH in silver pair enamelled repoussé case, by "Viet, Rotterdam," with pendulum balance wheel. Inv. 1916–205.

ALARM AND STRIKING WATCHES

197. FRENCH 17TH-CENTURY ALARM WATCH, by André Pichon à Lyon. Inv. 1954–151, Photos 616/54, 617/54.

From the Evan Roberts Collection:

198. ALARM WATCH with verge escapement in pinchbeck consular case, by Saml. Toulmin, Strand. No. 3495. Late 18th century. Inv. 1916–255.

199. VERGE ALARM WATCH in gold-plated case, by Meuron & Co. French. No. 18595. Late 18th century. Inv. 1916–256.

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200. GERMAN STACKFREED CLOCK-WATCH with dumb-bell foliot. Lent by the British Museum. Inv. 1955–162.

From the Evan Roberts Collection:

201. CLOCK WATCH in pinchbeck tortoise-shell case, with verge escapement, by Nath. Barrow, London. Late 17th century. Inv. 1916–259.

202. CLOCK WATCH in silver pair case, with verge escapement, by John Martin, London. Late 17th century. Inv. 1916–260.

203. VERGE CLOCK WATCH and Repeater in gold case, plate engraved, "Pour Eugenio Ferro in Treviso." Inv. 1916–261.

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204. JAEGER-LE COULTRE "MEMOVOX" ALARM WRIST-WATCH, 1953. Presented by De Trevars, Ltd. Inv. 1953–54.

See also Catalogue No. 441.

CYLINDER ESCAPEMENT

205. DIAGRAM OF CYLINDER ESCAPEMENT (see Plate VI).

The cylinder escapement was invented by George Graham about 1720, and may be regarded as an improvement of an escapement invented by Tompion in 1695. As the axis of the escape wheel is parallel to that of the balance this escapement is termed "horizontal" in distinction from the verge or vertical escapement in which the escape wheel axis is at right angles to the balance axis.

As shown in the diagram, there is an escape wheel with a series of pointed teeth which engage with an incomplete cylindrical shell, the latter being coaxial with the balance wheel. The inclined faces of the teeth engage with the lips of the shell and impart impulses which maintain the balance in vibration. At A.1 a tooth is locked in frictional contact with the inner surface of the shell and the balance continues to move in the direction indicated by the arrow until the shell occupies a position such as A.2. The balance then returns under the action of its spring and when it has moved far enough the wheel is unlocked, an impulse being given to the lip of the shell as indicated at A.3. As the tooth A passes out of the cylinder a second tooth B falls on the outer surface of the cylinder and remains at rest while the balance completes its swing and returns to unlock B, an impulse being next given as indicated at B.2. After this impulse B is locked on the inside of the cylinder in a position corresponding with A.1.

It will be noted that the action resembles that of the dead-beat escapement for clocks in that the locking faces are circular and there is no recoil of the escape wheel.

As the cylinder and escape wheel occupy a position such as A.2, it is impossible for the wheel teeth to be in the same plane as the body of the wheel and they are consequently at the ends of vertical projections. For the same reason it is necessary to cut away more of the cylindrical surface at the level of the body of the wheel.

This escapement was first employed by English makers, who used a brass escape wheel and, in their best movement, ruby cylinders, without, however, attaining any marked success. Later it was used in Switzerland with much better results in conjunction with a small steel escape wheel, and until about the end of the 19th century it was very extensively used in the watches known as "Geneva" watches.

A number of watches with this escapement are shown, and there is a model, on a magnified scale, in an adjacent case (see Catalogue No. 327). Inv. 1928–1182.

From the Evan Roberts Collection:

206. CYLINDER WATCH in silver case, by Geo. Graham, London. No. 5223. 18th century. Inv. 1916–146, Photo 3378.

207. CYLINDER WATCH in silver repoussé pair case, by Just. Vulliamy, London. No. nxo. 18th century. Inv. 1916–159, Photo 3378.

208. CYLINDER WATCH in pinchbeck inner case, tortoise-shell outer case, by L. Kendall, London. 18th century. Inv. 1916–145.

209. CYLINDER WATCH in silver pair case, by Tho. Mudge and W. Dutton, London. No. 597. Hall-mark 1759. Inv. 1916–150.

210. CYLINDER WATCH in enamelled consular case, by Josiah Emery, London. No. 2438. About 1780. Inv. 1916–141.

211. CYLINDER WATCH, by Thos. Reid, Edinburgh. No. 2520. About 1800. Inv. 1916–151.

212. CYLINDER WATCH in silver inner case and tortoise-shell outer case, by Barwise, London. Steel escape wheel. No. 3275. Hall-mark 1803. Inv. 1916–157.

213. CYLINDER WATCH in silver case, with going barrel. Hall-mark 1839. Inv. 1916–155.

214. CYLINDER WATCH in silver case, by Breguet. "Subscription" watch with hour hand only. No. 445. Inv. 1916–163.

215. CYLINDER WATCH in silver case, by Breguet et Fils. "Subscription" watch. No. 1350. Inv. 1916–164.

216. CYLINDER WATCH in enamelled gold case, La Croix, Geneva. No. 5666. Inv. 1916–169.

217. CYLINDER WATCH in gold engraved case, by Jodin, Paris. No. 352. About 1800. Inv. 1916–170.

218. CYLINDER WATCH in gold repoussé case, by Moulinié, Bautte & Moynier, Geneva. Inv. 1916–171.

219. FLAT WATCH MOVEMENT with horizontal escapement, F. & A. Meylan, Geneva. No. 23093. Inv. 1916–298.

From the Bruno Roberts Collection:

220. ENGLISH CYLINDER WATCH MOVEMENT, by Geo. Graham, London. No. 4796. Middle 18th century. Inv. 1920–498.

221. CYLINDER WATCH MOVEMENT, by Jeffrys & Jones, London, No. 436, with steel escape wheel. About 1800. Inv. 1920–501.

222. THIN SWISS CYLINDER WATCH MOVEMENT. About 1800. Inv. 1920–505.

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223. CYLINDER WATCH MOVEMENT, by Jean Antoine Lepine, Paris. About 1800. Constructed according to the thin "Lepine" calibre, introduced by this maker, in which the top plate is replaced by bars. Presented by G. Pinchard, Esq. Inv. 1934–179.

224. DETAILS OF A CYLINDER ESCAPEMENT. Inv. 1912–277.

BREGUET'S CYLINDER ESCAPEMENT

225. DIAGRAM OF BREGUET'S CYLINDER ESCAPEMENT.

This diagram shows a special form of cylinder escapement used by Breguet to a limited extent in the early part of the 19th century.

The incomplete cylindrical shell overhangs below the bottom pivot, an arrangement which permits the more simple shape shown for the escape wheel teeth. The acting surface consists of a shaped ruby.

This escapement is employed in the adjacent clock watch made by Breguet in 1797–8 (Catalogue No. 226). Inv. 1928–1183.

From the Evan Roberts Collection:

226. CLOCK WATCH with ruby cylinder overhanging below bottom pivot, in gold case, by Breguet. No. 300. 1797–8. Inv. 1916–262.

DUPLEX ESCAPEMENT

227. DIAGRAM OF DUPLEX ESCAPEMENT (see Plate VII).

This escapement was introduced towards the end of the 18th century and has been credited to various inventors. In the early years of the 19th century it was extensively used in high-class watches.

It received its name from the two escape wheels, which were employed in its original form, one for effecting the locking and the other for the impulse, but these two wheels were afterwards made as one wheel with two sets of teeth.

As shown in the diagram a set of flat pointed long teeth successively engage with a notched jewelled roller mounted on the axis of the balance wheel. When the balance so moves that the notch allows the escape wheel to advance, one of the second set of teeth, which project upward, engages with a jewelled pallet mounted on a projecting piece secured to the axis of the balance wheel and imparts an impulse to the latter. At the end of this impulse the wheel is free to move until a long tooth falls on the jewelled roller and the wheel is again locked.

It will be seen that an impulse is given to the balance on alternate vibrations only and that, in addition to the main impulse, the balance receives a subsidiary impulse from the long teeth engaging with the notch. These two impulses are known as the great lift and small lift respectively.

Examples of watches with this escapement are shown adjacently, and a large-scale model may be seen in a neighbouring showcase (see Catalogue No. 328). Inv. 1928–1189.

228. DUPLEX WATCH MOVEMENT by Recordon, with compensation curb. No. 7122. Lent by G. J. Fenn-Wiggin, Esq. Inv. 1952–58.

From the Evan Roberts Collection:

229. DUPLEX WATCH in silver hunter case, by Vulliamy, London. No. xxam. Hall-mark 1823. Inv. 1916–182.

230. DUPLEX WATCH in silver case, by Thos. Earnshaw, 119, High Holborn, London. No. 4521. Hall-mark 1824. Inv. 1916–179.

231. DUPLEX WATCH in silver hunter case, by Molyneux & Sons, London. No. 1368. Hall-mark 1830. Inv. 1916–180.

232. DUPLEX WATCH in silver case, by James McCabe, London. No. 2598. Hall-mark 1833. Inv. 1916–183.

From the Bruno Roberts Collection:

233. SWISS DUPLEX THREE-QUARTER PLATE WATCH MOVEMENT, with fusee made by Grandjean Père et Fils. About 1830. Inv. 1920–550.

234. SWISS GOING-BARREL WATCH MOVEMENT, with duplex escapement and steel escape wheel. Middle 19th century. Inv. 1920–509.

235. AMERICAN GOING-BARREL KEYLESS DUPLEX "ADDISON" WATCH MOVEMENT of about 1890 ("Waterbury" type). Inv. 1920–511.

LEVER ESCAPEMENTS

236. DIAGRAM OF RACK-LEVER ESCAPEMENT.

This escapement was patented by Peter Litherland in 1791 and was employed to some extent on English watches about the beginning of the 19th century. A similar escapement had, however, been invented by the Abbé Hautefeuille in France as early as 1722.

An anchor carrying the pallets is secured to a lever at one end of which there is a toothed rack gearing with a pinion on the axis of the balance. The arrangement is subject to the disadvantage that the balance is always in connection with the lever and pallets, that is, it is an "undetached" form of escapement.

Examples of watches with this escapement are shown adjacently. Inv. 1928–1186.

From the Evan Roberts Collection:

237. RACK-LEVER WATCH in pinchbeck pair case, by P. Litherland & Co., Liverpool. No. 306. About 1800. Inv. 1916–190.

238. WATCH MOVEMENT with rack-lever escapement, by R. Roskell. No. 8225. Inv. 1916–276.

From the Bruno Roberts Collection:

239. LEVER WATCH MOVEMENT, with rack lever straight-line escapement, by P. Litherland & Co., Liverpool. No. 27. Early 19th century. Inv. 1920–519.

240. DIAGRAM OF CRANK ROLLER ESCAPEMENT.

This form of lever escapement was introduced about the end of the 18th century and was used considerably in the early part of the 19th century. The invention has been claimed for both Edward Massey and George Margetts.

Mounted on the balance staff there is a short cylindrical piece, known as the roller, carrying two projections between which there is a jewel pin. This pin engages with a notch at the end of the lever on which the anchor carrying the pallets is mounted. The motion of the lever is restricted by banking pins, and during the greater parts of its vibrations the balance is free from engagement with the lever. This feature constitutes a detached escapement, and gives great advantage in comparison with the undetached form of rack lever escapement.

In some cases a finger or tooth projecting from the roller is employed instead of the jewel pin shown in the diagram.

Specimens of watch movements with this escapement are shown adjacently. Inv. 1928–1187.

From the Evan Roberts Collection:

241. CRANK-ROLLER LEVER WATCH with Arabic numerals on the dial, by S. Weatherilt, Liverpool. No. 741. Inv. 1916–191.

From the Bruno Roberts Collection:

242. LEVER WATCH MOVEMENT, with crank roller, by M. I. Tobias & Co., Liverpool. No. 8386. Early 19th century. Inv. 1920–516.

243. DIAGRAM OF ENGLISH LEVER ESCAPEMENT (see Plate VII).

This form of escapement came into use in the early part of the 19th century, and it is the form which has been most extensively used in English hand-made watches.

Its action is described in connection with a model, on a magnified scale, shown in an adjacent case (see Catalogue No. 329).

The lines joining the pallet staff with the balance staff and the escape wheel axis respectively are at right angles and it is known as a right-angled escapement in comparison with the straight-line escapement in which these three axes are in the one line, as is usual in Swiss and American watches with club-shaped teeth.

Examples of watch movements with this escapement are shown adjacently.

Inv. 1928–1184.

From the Evan Roberts Collection:

244. LEVER WATCH in silver case, by Thos. Earnshaw, London. No. 4776. Hall-mark 1831. Inv. 1916–195.

245. BAR MOVEMENT with straight-line lever escapement. No. 16670. Inv. 1916–287.

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246. LEVER WATCH, with a Geneva stop to prevent over-winding. In gold case, hall-mark 1830. Presented by Sir Edwin Durning-Lawrence, Bart. Inv. 1901–76.

247. DETAILS OF A LEVER ESCAPEMENT. Inv. 1912–278.

248. DIAGRAM OF CLUB TOOTH LEVER ESCAPEMENT.

This form of escapement was first used extensively by the Swiss and is now in general use for pocket watches except the highest grades of English-made watches.

As shown in the diagram, the tips of the teeth take the form of inclined planes and the impulse is obtained in two stages, first by the engagement of the planes of the teeth with an edge of the pallet and next by the engagement of the teeth with the impulse planes of the pallets.

The club tooth has the advantage of retaining oil better than the pointed tooth, of requiring less "drop," as the free motion of the wheel between engagements with the pallets is termed, and also of being less fragile, and its employment has increased considerably during the present century.

Movements with this escapement are shown adjacently, and there is a large-scale working model in a neighbouring showcase (Catalogue No. 330). Inv. 1928–1185.

From the Evan Roberts Collection:

249. LEVER WATCH in silver case, by "Piguet et Meylan." No. 46133. Inv. 1916–196.

From the Bruno Roberts Collection:

250. LEVER WATCH MOVEMENT, with club-toothed escape wheel, and forked lever banking on the escape wheel arbor, by Robt. Roskell, Liverpool. No. 32224. About 1830. Inv. 1920–522.

251. LEVER WATCH MOVEMENT, with club-tooth escape wheel and straight-line escapement, by United States Watch Co. No. 32659. Inscribed "John F. Sylvester, N.Y." About 1870. Inv. 1920–554.

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252. GENEVA LEVER WATCH MOVEMENT, with steel club-toothed escape-wheel and going-barrel. The bars engraved. Presented by J. A. Cousins, Esq.

Inv. 1951–246, Photo 425/51.

253. MINIATURE LEVER WATCH by Piguet & Meylan. Presented by H.M. Queen Mary. Inv. 1952–1, Photos 130/52, 131/52, 132/52.

254. MOVEMENT OF JAEGER-LE COULTRE WATCH MODEL 72 (1953): "THE SMALLEST WATCH IN THE WORLD." Presented by De Trevars, Ltd. Inv. 1953–53.

SPECIAL LEVERS

From the Bruno Roberts Collection:

255. LEVER WATCH MOVEMENT, by Litherland, Davies & Co., Liverpool, No. 11197, with dead-beat anchor escapement, large balance wheel beating seconds, and crank roller, the latter invented by Edward Massey in the early part of the 19th century. Inv. 1920–557.

256. WATCH MOVEMENT, by Samuel Smith, Coventry, No. 41, with the escapement patented by him in 1812. A vertical escape wheel with five teeth engages with pallets which are mounted on a toothed wheel gearing with a pinion on the balance. Inv. 1920–513.

STOP-WATCHES AND POCKET CHRONOGRAPHS

257. STOP-WATCH, by Martin, Royal Exchange, London, with jump quarter-seconds. Late 18th century. Bequeathed by G. H. Baillie, Esq. Inv. 1953–23.

258. CYLINDER STOP-WATCH, by Geo. Graham. No. 6296. Hall-mark 1748. Lent by The Victoria and Albert Museum. Inv. 1953–380, Photos 696/54, 697/54.

259. CHRONOGRAPH WATCH, by Fatton & Co., London, with two dials. The back dial has a centre seconds inking chronograph hand as patented by Fatton. Hall-mark 1824. Lent by C. A. Ilbert, Esq. Inv. 1952–340, Photo 375/53.

260. FRENCH VERGE STOP-WATCH, with centre seconds-hand, by Le Roi. About 1750. Presented by Major E. O. Henrici. Inv. 1936–132.

From the Bruno Roberts Collection:

261. ENGLISH VERGE WATCH MOVEMENT, by Kenneth Maclennan, London, No. 735, with centre seconds and stop work acting on the escape wheel. About 1800. Inv. 1920–490.

262. ENGLISH LEVER WATCH MOVEMENT, with independent centre seconds, by Thos, Tarleton, Liverpool. No. 7271. Middle 19th century. Inv. 1920–543.

From the Evan Roberts Collection:

263. "GENEVA LEVER" WATCH with independent centre seconds, in silver case. No. 10943. Inv. 1916–217.

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264. INDEPENDENT CENTRE SECONDS CHRONOGRAPH, with cylinder escapement and two complete sets of hands, one set for chronograph mechanism and one for time. Lent by Gregory Tovey, Esq. Inv. 1935–495.

See also Catalogue Nos. 436 *to* 438.

CHRONOMETER WATCHES & WATCHES WITH TEMPERATURE COMPENSATION

From the Evan Roberts Collection:

265. CYLINDER WATCH with compensator acting on curb pins, by John Arnold, London. No. 1. Late 18th century. Inv. 1916–149.

266. CYLINDER WATCH with curb compensation, by Jno. R. Arnold, London. No. 3636. Early 19th century. Inv. 1916–147.

From the Bruno Roberts Collection:

267. ENGLISH DUPLEX WATCH MOVEMENT, by S. and C. Joyce, London. No. 1185. Early 19th century. With compensation curb in which the curb pins are at the ends of bimetallic strips. Inv. 1920–507.

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268. CHRONOMETER WATCH, by Thomas Earnshaw, with curb temperature compensating device. No. 728. About 1800. The case is not original. Bequeathed by Edwin Earnshaw. Inv. 1915–408, Photo 3377.

From the Bruno Roberts Collection:

269. POCKET CHRONOMETER MOVEMENT, made by John Arnold, London, towards the end of the 18th century, with compensation balance, helical balance spring, and detent escapement patented by him in 1775–1782. Maker's No. 70/371. Inv. 1920–544.

From the Evan Roberts Collection:

270. CHRONOMETER WATCH in silver case, by John Arnold & Son, London. No. 360/661. Late 18th century. Inv. 1916–184.

271. CHRONOMETER WATCH in silver case, by Thos. Earnshaw, London. No. 422. Early 19th century. Inv. 1916–187, Photo 3377.

272. CHRONOMETER WATCH in silver case, by Thos. Earnshaw, London. No. 837. Hall-mark 1825. Inv. 1916–188.

273. CHRONOMETER WATCH, in silver case, by "J. R. Arnold, Chas. Frodsham, 84, Strand, London." With half-plate movement. No. 6530. Hall-mark 1833. Inv. 1916–186.

274. WATCH MOVEMENT with chronometer escapement, by Dimier Freres et Cie, Fleurier. No. 28981. Inv. 1916–264.

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275. GOLD REPEATING WATCH, No. 2978, by Breguet, with curb compensator and parachute. Lent by Miss G. M. Hodges. Inv. 1950–28.

276. SWISS LEVER WATCH, with tourbillon movement. Bequeathed by Cyril G. B. Judd, Esq. Inv. 1938–318, Photos 314/47, 315/47.

See also Catalogue Nos. 332 *and* 333.

SPECIAL DIALS, CALENDARS, CENTRE SECONDS, ETC.

277. ENGLISH WATCH of about 1660, by William Crayle in the Strand, with wandering hour-figure (see Plate VIII). Inv. 1954–189, Photos 614/54, 615/54.

278. VERGE WATCH, by Peter Garon, London. The hour is indicated by the sun or moon in the sector. Minute hand and a second dial. About 1695. Lent by C. A. Ilbert, Esq. Inv. 1952–334, Photo 373/53.

279. VERGE WATCH, by J. Banks, Nottingham. The hours and minutes are indicated by one hand. Central hour disc revolves with minute hand but slightly lagging. End 17th century. Lent by C. A. Ilbert, Esq. Inv. 1952–335, Photo 373/53.

280. VERGE WATCH, by Peter Fardoil, London. The hours are indicated on a sector by a moving pointer which, on reaching the right-hand end, flicks back. Concentric minute hand. Hall-mark 1700. Lent by C. A. Ilbert, Esq. Inv. 1952–336, Photo 602/52.

From the Evan Roberts Collection:

281. VERGE WATCH in silver pair case, by Jno. Harrison, London. Centre seconds. No. 400. Hall-mark 1784. Inv. 1916–106.

282. VERGE WATCH, by Ralph Gout, London, combined with pedometer. No. 224. About 1800. Inv. 1916–107.

283. CALENDAR WATCH with lever escapement, by Richd. Clarke, London. No. 124. Early 19th century. Inv. 1916–214.

284. CYLINDER WATCH in silver case, by Vaucher, with hours shown in aperture under pendant. No. 3478. Inv. 1916–172.

285. CALENDAR WATCH in silver case, with cylinder escapement; balance wheel under the dial. Hall-mark 1860. Inv. 1916–213.

286. KEYLESS LEVER WATCH, with centre seconds, beating tenths of seconds, by Wm. Williams, Bury. No. 19289. 1890. Inv. 1916–218.

287. WATCH made for the Turkish market about 1800, by George Prior, London. Lent by the Antiquarian Horological Society. Inv. 1954–63.

288. HALF-HUNTER LEVER WATCH with calendar at back giving days of the week and of the month. Bequeathed by Cyril G. B. Judd, Esq. Inv. 1938–321.

REGULATING MECHANISMS

289. VERGE WATCH of about 1640, by Richard Masterman, London. An early example of tangent-screw regulation. Lent by C. A. Ilbert, Esq. Inv. 1952–330, Photo 381/53.

290. ENGLISH "PURITAN" WATCH of about 1650, with later balance-spring adjustable by worm. Inv. 1954–188, Photos 612/54, 613/54.

291. VERGE WATCH, by Thomas Tompion, with tangent-screw to set up mainspring but regulation by the small dial. Lent by C. A. Ilbert, Esq. Inv. 1952–332, Photo 601/52.

292. VERGE WATCH, by Jacobus Markwick, London, with Barrow-type regulator. Lent by the British Museum. Inv. 1955–164.

From the Evan Roberts Collection:

293. VERGE WATCH with tangent-screw regulator, by W. I. Ward, London. No. 2532. Hall-mark 1794. Inv. 1916–208.

294. VERGE WATCH with "hare and snail" regulator, by Willm. Smith, London. No. 9709. Early 19th century. Inv. 1916–209.

295. VERGE WATCH with visible rack regulator, by Thierry, Caen. Inv. 1916–210.

WINDING DEVICES

From the Bruno Roberts Collection:

296. SWISS LEVER WATCH MOVEMENT, of about 1870, by U. Humbert Ramuz, Chaux de Fonds, with rack keyless mechanism with "pumping" action of form patented by Edward Massey in 1814. Inv. 1920–541.

297. ENGLISH GOING-BARREL KEYLESS CYLINDER WATCH MOVEMENT, by Viner & Co., London, No. 1988, with rack and pinion "pumping" keyless mechanism which does not operate the hands. Early 19th century. Inv. 1920–535.

298. SWISS KEYLESS CYLINDER WATCH MOVEMENT, by A. B. Savory, with "pumping" keyless mechanism actuated by a chain; the hands are set by a milled nut on the cannon pinion. Early 19th century. Inv. 1920–538.

299. VERGE WATCH MOVEMENT, by Bright & Sons, Sheffield, No. 12962, with "pump" winding arrangement actuated by a chain. Early 19th century. Inv. 1920–558.

300. ENGLISH LEVER GOING-BARREL KEYLESS WATCH MOVEMENT, of about 1830, by Arnold and Dent, London. No. 4667. A stem with bevel gear was employed for winding and the hands were set by an ordinary key. Inv. 1920–536.

301. ENGLISH LEVER WATCH MOVEMENT, of about 1840, by Duncan, London, No. 2023, with special form of maintaining power mechanism. The maintaining ratchet wheel has contrate teeth and is controlled by a click which is on the end of a spring and acts through a hole in the bottom plate. Inv. 1920–562.

302. ENGLISH LEVER GOING-BARREL KEYLESS WATCH MOVEMENT, of about 1870, with the rocking bar keyless mechanism generally employed in English watches, which was patented by Gustavus Huguenin in 1855. Inv. 1920–539.

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303. SWISS WATCH, with unusual form of keyless winding mechanism. About 1850. Presented by G. R. Kirby, Esq. Inv. 1936–133.

304. LEVER WATCH MOVEMENT, by Thos. Russell & Son, with up-and-down indicator for winding. No. 108241. 19th century. Bequeathed by Cyril G. B. Judd, Esq. Inv. 1938–320.

305. JAEGER-LE COULTRE AUTOMATIC WRIST-WATCH (1953) with reserve power indicator. Presented by De Trevars, Ltd. Inv. 1953–55.

306. MOVEMENT OF JAEGER-LE COULTRE AUTOMATIC WRIST-WATCH (1953) showing self-winding mechanism. Presented by De Trevars, Ltd. Inv. 1953–56.

REPEATERS AND MUSICAL REPEATERS

From the Evan Roberts Collection:

307. VERGE REPEATING WATCH in pinchbeck-shagreen pair case, by Jno. Kentish, London. No. 908. 18th century. Inv. 1916–223.

308. QUARTER REPEATING WATCH with horizontal escapement, in gold case. English. No. 3431. Hall-mark 1813. Inv. 1916–239.

309. VERGE REPEATING WATCH in silver case, by Berthoud, Paris. No. 976. Inv. 1916–234.

310. VERGE REPEATING WATCH in gold case, by Breguet, Paris. About 1800. Inv. 1916–236.

311. REPEATING WATCH with cylinder escapement in gold case, by Lacroix, Turin. No. 8044. 1833. Inv. 1916–237.

312. REPEATING WATCH with cylinder escapement, parachute, and curb compensator, in gold case, by Breguet. No. 357. About 1800. Inv. 1916–238.

313. REPEATING WATCH with cylinder escapement, in silver case, by Breguet. No. 4128. Inv. 1916–247.

314. HALF-QUARTER REPEATING WATCH with cylinder escapement, in silver case, by Thos. Earnshaw, 119, High Holborn, London. No. 4502. Hall-mark 1823. Inv. 1916–242.

315. MUSICAL REPEATING WATCH with cylinder escapement, in silver case, by Breguet. No. 225. About 1800. Inv. 1916–248, Photos 597/50, 598/50.

316. MUSICAL REPEATER with cylinder escapement, enamelled. No. 8594. Inv. 1916–263.

317. REPEATING WATCH with cylinder escapement, in silver case, by Ellicott, London. No. 5083. Inv. 1916–241.

From the Bruno Roberts Collection:

318. ENGLISH QUARTER-REPEATER CYLINDER WATCH MOVEMENT, with steel escape wheel, by Robt. Roskell, Liverpool. No. 10073. Early 19th century. Inv. 1920–534.

319. ENGLISH QUARTER-REPEATER WATCH MOVEMENT, with duplex escapement, by Viner & Co., London. No. 2021. About 1830. Inv. 1920–549.

320. SWISS REPEATER CYLINDER WATCH MOVEMENT, with fusee, brass escape wheel, and pierced bridge balance cock, made by Terroux, l'aîné, Geneva, 1779. Inv. 1920–530.

321. QUARTER-REPEATER GOING-BARREL CYLINDER WATCH MOVEMENT, of French or Swiss make, with brass escape wheel, balance wheel under the dial, and fitted with two bells. About 1800. Inv. 1920–533.

322. SWISS MINUTE-REPEATER CYLINDER WATCH MOVEMENT, with repeating work mounted at the back. Middle 19th century. Inv. 1920–531.

323. SWISS MUSICAL WATCH MOVEMENT, with cylinder escapement and a disc carrying pins which engage with short steel springs and give the notes required. About 1800. Inv. 1920–527.

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324. QUARTER REPEATING WATCH, by Quare, London. No. 446. About 1700. Lent by G. J. Fenn-Wiggin, Esq. Inv. 1948–88.

325. QUARTER REPEATING LEVER CHRONOGRAPH WATCH. Bequeathed by Cyril G. B. Judd, Esq. Inv. 1938–322.

326. HALF-QUARTER REPEATING CHRONOMETER WATCH MOVEMENT, by Thos. Earnshaw. Bequeathed by Cyril G. B. Judd, Esq. Inv. 1938–317.

See also Catalogue Nos. 444 *and* 445.

ESCAPEMENT MODELS

327. CYLINDER ESCAPEMENT. Made and presented by J. M. Kleyser, Esq.

The horizontal cylinder escapement was perfected by George Graham about 1720, and may be regarded as a modification for use in watches of the dead-beat escapement which he had earlier invented for clocks. The model represents the action on a magnified scale.

The escape wheel teeth are pointed and engage with an incomplete cylinder which is mounted on the same axis as the balance wheel. Locking of the escape wheel is effected alternately on the outer and inner surfaces of the cylinder which are highly polished, and the impulses are given by the action of the inclined faces of the teeth upon the edges of the cylinder. As the balance may swing through a large angle, it is not possible to have the teeth in the same plane as the body of the wheel, and the teeth are consequently mounted on the ends of vertical arms.

This escapement was formerly very extensively employed, more especially in Swiss and French watches. Inv. 1925–51, Photos 159/48, 159A/48.

328. MODEL OF THE ESCAPEMENT EMPLOYED IN THE EARLY "WATERBURY" WATCHES.

This model shows, on a large scale, the escapement which was employed in the Waterbury watch, which was first put on the market in the U.S.A. in 1880, and was one of the first watches to be sold at a price which made it available for the multitude.

The escapement is a modification of the so-called "duplex" type, which was invented during the second half of the 18th century. In this mechanism the escape wheel is provided with two sets of teeth, one set for impulsing and one for locking.

The locking teeth are long and pointed and fall in turn into a notch in the axis of the balance wheel. As the balance rotates in an anti-clockwise direction it allows one of these teeth to escape from the notch, and one of the impulsing teeth then engages with a pin mounted on a piece projecting from the balance axis, imparting an impulse to the balance. At the end of this impulse the escape wheel is free to rotate until the next long tooth falls on the balance axis, when the wheel is again locked. It remains locked during the clockwise return swing of the balance, but just before the middle of the next anti-clockwise swing the long tooth falls into the notch in the axis and the cycle of operations is complete.

It will be seen that an impulse is given to the balance at alternate vibrations and that in addition to the main impulse the balance receives a subsidiary small impulse from each long tooth as it engages with the notch. The two impulses are known as the "great lift" and the "small lift" respectively.

An example of a Waterbury watch is exhibited adjacently. Inv. 1938–554.

329. LEVER ESCAPEMENT. Presented by T. A. Winter, Esq.

This model represents, on a magnified scale, the detached lever escapement which, in various modified forms, is now almost universally employed for pocket watches. It was invented by Thomas Mudge about 1750, but was not used to any great extent until a much later date.

An escape wheel of 15 teeth engages with two pallets which are mounted on a lever. One end of this lever is notched to engage with a pin carried by a disc or "roller" on the balance axis, and the motion of the lever is limited by two pins, known as "banking" pins.

A pin, known as the "safety" pin, which is mounted on the lever near to the notch, prevents the lever from moving except when engaged by the roller pin.

In Mudge's original form the locking faces of the pallets were circular, as in the dead-beat escapement for clocks, but in the later forms, with which success was obtained, the locking faces are straight, and are so inclined that an escape wheel tooth, pushing against a locking face, tends to "draw" it towards the wheel and, by so keeping the lever against a banking pin, prevents the safety pin from continually touching the roller. This supplementary invention of "draw," which rendered the escapement practicable, appears to have been due to Josiah Emery.

This form of escapement is known as "detached" because the balance is free from any engagement during the greater portion of its swing.

In actual watches the acting surfaces of the pallets and the roller pin are jewels, and in the modern Swiss form of the escapement the escape-wheel teeth are club-shaped and the escapement is laid out so that the pallet staff, the balance axis and the escape wheel pivots lie in a straight line. Inv. 1928–300, Photo 160/48.

330. MODEL OF SWISS LEVER ESCAPEMENT (Scale 10:1). Presented by A. W. Whiting, Esq.

In this form of the lever escapement, also known as the club-tooth lever escapement, the tips of the escape-wheel teeth take the form of inclined planes and the impulse is obtained in two stages, first by the engagement of the planes of the teeth with an edge of the pallet and next by the engagement of the edge of a tooth with the impulse plane of a pallet. The club tooth has the advantage of retaining oil better than a pointed tooth, of requiring less "drop" (as the free motion of the wheel between engagements with the pallets is termed) and also of being less fragile and its employment in watches has increased considerably during the present century.

In this escapement it is usual to mount the balance staff, the pallet staff and the escape-wheel staff all in the same straight line, and with this layout the escapement is sometimes referred to as the "straight line escapement."

An additional interesting feature of the present model is that the balance-spring is of the "overcoil" shape invented by Breguet about 1800 which gives better isochronism between large and small arcs of swing than the more usual flat spiral employed in watches. Inv. 1951–25, Photo 376/51.

VARIOUS MECHANISMS

331. CLOCK MOVEMENT SHOWING FUSEE.

The fusee is a device for obtaining a constant driving torque from a spring as it uncoils, and has been widely employed in clocks, watches and chronometers.

It consists of a tapering drum with a spiral groove cut in it, and the pull of the main-spring is exerted through a cord or chain which is unwound from this groove on to the outside of the drum or "barrel" containing the spring. When the spring is fully wound and exerting its greatest pull the cord is unwinding from the smaller end of the fusee,

where it has only a small leverage, while when the spring is nearly run down the chain pulls at the wider end of the fusee, with a greater leverage. By suitably shaping the fusee the torque on its axis can be made quite uniform for all states of the spring.

In the early foliot clocks of the 14th and 15th centuries the rate of the clock depended largely upon the magnitude of the driving force. When the first spring-driven clocks were made, probably towards the end of the 15th century, it became essential to find some means of obtaining a constant driving torque from an uncoiling spring.

There is some evidence for an isolated spring-driven clock with a fusee as early as 1430, and the fusee mechanism is shown in sketches made by Leonardo da Vinci in 1490, but the earliest fusee clock which can be dated with certainty is one made by Jacob Zech (Jacob the Czech) in 1525.

The application of the pendulum to clocks about 1660 and the balance-spring to watches about 1675 and the subsequent invention of better escapements caused the timekeeping of clocks and watches to be less affected by variations in the driving force, and hence the fusee was no longer essential and its use has therefore been to a large extent discontinued, though it is still almost invariably employed in chronometers, in which the highest accuracy is essential. Inv. 1883–74, Photo 158/48.

332. "TOURBILLON" WATCH. Bequeathed by Major E. R. Rivers.

This watch embodies a "tourbillon" movement of the type invented by A. L. Breguet in 1781.

Unless the balance-wheel and spring of a watch are perfectly poised, the rate of the watch will depend upon the position in which it is held, and Breguet's tourbillon was an attempt to overcome this difficulty.

In this arrangement, the balance-wheel and spring, together with the escape-wheel and lever, are mounted in a cage which rotates once per minute, so that the balance-wheel goes through a full cycle of positions once per minute.

The third wheel of the watch train drives a pinion on whose shaft the rotating cage is mounted. This shaft passes freely through the centre of the fourth wheel, which is not keyed to it as usual but is fixed. The pinion coaxial with the escape-wheel is carried round by the cage and rolls round the outside of the fixed fourth wheel, causing the escape-wheel to rotate relative to the cage and to drive the lever of the escapement in the usual way.

The action can be best seen by studying it in actual operation.

The watch exhibited, which dates from the present century, is fitted with a typical bi-metallic compensation balance and a steel overcoil balance-spring. Inv. 1944–9.

See also Catalogue No. 276.

333. "KARRUSEL" DECK WATCH. Presented by R. McV. Weston, Esq.

This represents a later development of Breguet's invention, shown adjacently (see Catalogue No. 332), in which, to avoid position errors, the whole escapement, including the balance-wheel and spring, was mounted in a cage rotating once per minute.

In the "karrusel," patented by Bonniksen of Coventry in 1892, the escapement rotates once in 52½ minutes. The 10-tooth pinion coaxial with the third wheel, which rotates once every 7½ minutes, engages with a 70-tooth wheel to which the cage is attached and which rotates once in 52½ minutes. The fourth wheel shaft passes freely through the centre of the cage, and the fourth wheel drives the escape-wheel pinion, whose bearings are mounted in the cage. The escape-wheel is therefore driven directly in the normal way and not, as in the tourbillon, through the rotating cage.

The watch exhibited, by Richard Thorneloe of Coventry, dates from the end of the 19th century.

[See British Patent Specification No. 21421 of 1892.] Inv. 1952–255, Photo 70/53.

334. SKELETON TIMEPIECE. Presented by R. N. Shaw, Esq.

This French timepiece was made about the middle of the 19th century and includes a number of interesting features. It has a centre-seconds arrangement, a pin wheel escapement, a gridiron compensation pendulum and a weight remontoire.

A remontoire is a device for obtaining a constant driving force on the escapement and in this example, though not always, it is employed as a substitute for a fusee. The main driving train is arranged to wind up, about every sixteen seconds, a subsidiary system which in turn drives the escapement.

The remontoire is introduced between the third and fourth wheels of the train, and the subsidiary driving system consists of a weight on the end of a lever which is connected by an endless cord with pulleys mounted on the arbors of the third and fourth wheels. The action of the weight drives the fourth wheel and the weight is lifted up by intermittent motion of the third wheel. The latter takes the form of a worm wheel driving a worm screw on the axis of which there is a large light wheel carrying four pins which engage with a stop secured to the lever. As the fourth wheel moves, the lever and its weight

descend, and the stop moves away from a pin and releases the main driving train. By means of the pulley and cord, the motion of the third wheel then lifts the weight, an action which is accompanied by a movement of the stop which intercepts the next pin on the large light wheel and again locks the main train. Inv. 1924–295.

335. CLOCK WITH CONICAL PENDULUM. Presented by Arnold F. Jones, Esq.

In this small timepiece the motion of the wheel train is controlled by a ball moving in a horizontal circle and supported, from a fixed point above, by a cord which describes a cone.

The ball is maintained in motion by a light rotating arm at the end of the train, but unless special means, which are not employed in this case, are adopted, accuracy cannot be obtained by this method. Conical pendulums have, however, been employed for special purposes where uniform continuous motion is required. Inv. 1928–674.

336. "ATMOS II" SELF-WINDING CLOCK. Presented by Messrs. De Trevars, Ltd.

This clock is automatically wound by changes of atmospheric temperature and pressure. A fall of temperature of 3° F. provides enough power to drive the clock for over 24 hours.

The driving motor of the clock, a sectioned example of which is shown on the left, consists of a drum on the inside of which is mounted a flexible metallic bellows. The space between the bellows and the outer drum casing is hermetically sealed and contains ethyl chloride, the vapour pressure of which varies very rapidly with temperature. Increase of temperature raises this pressure and causes the bellows to expand against a spring. A similar effect would be produced by a fall of barometric pressure. By means of a connecting system, the expansion and contraction of the bellows is caused to wind up the clock mainspring, which has a year's reserve of power. Arrangements are made to prevent overwinding and the mainspring normally operates under nearly uniform tension.

The design of the clock itself has many features of interest.

The horizontal balance-wheel is controlled by an elinvar spring, whose elasticity does not vary appreciably with temperature. The balance, which is driven by a detached lever escapement, makes only 1,440 complete oscillations in 24 hours, compared with 43,200 for a seconds pendulum.

Owing to the slow action of the moving parts and the precision of their finish, the use of oil in the clock has been entirely eliminated. Inv. 1939–259 and 1946–237.

336a. VERGE CALENDAR WATCH by George Seydell, Coln an der Sprre. Lent by the British Museum.

This watch, which dates from about 1660, shows the hour, day of the week, the month, and the age and phase of the moon, and is fitted with a "pendulum" balance.
Inv. 1955–163.

WATCH MAGNETISM

337. THE EFFECT OF MAGNETISM ON A WATCH. Photographs presented by the United States Bureau of Standards, Washington.

The exhibit shows the effect of a magnetic field on the rate of a watch.

The photograph A (top left) shows, by means of iron filings, the magnetic field in the neighbourhood of a non-magnetic balance-wheel, and of a balance-wheel of the usual cut bi-metallic form, whose arms are of brass and steel. The detailed construction of the two balances is shown in diagram B (bottom left).

The photograph C (top right) shows similarly the magnetic field in the neighbourhood of a non-magnetic balance-spring made of elinvar, and a normal steel balance-spring.

The effect of magnetisation on the rate of the watch is illustrated by the graph D (bottom right). The upper curve shows the rate of a watch with magnetic balance and spring after being placed in a magnetic field for a few seconds and then removed; the successive points show the rate for various field strengths. The final point on the right shows the return of the watch to its previous rate after demagnetisation.

The lower curve, obtained by similarly treating a watch with a non-magnetic balance and spring, shows that in this case the magnetic field has practically no effect on the rate of the watch.

[See The Horological Journal, Vol. 76, p. 68 (July, 1934).] Inv. 1940–30.

V. CHRONOMETERS

CHRONOMETERS are mechanical timekeepers specially designed to keep accurate time on board ship.

The position of a ship at sea is known when its latitude and longitude have been determined. The navigator can find his latitude by observing the sun or stars, but to find his longitude he must in addition know the standard time at which the observation was made, *i.e.*, the time at some place whose longitude is known. The only practicable method of finding standard time at sea is to carry on board ship an accurate timekeeper; before accurate marine timekeepers were available navigators on long ocean voyages could only very roughly estimate their longitude, and mistaken estimates caused many shipwrecks.

John Harrison in 1728–59 was the first to construct instruments which would keep sufficiently accurate time on board ship; he was quickly followed by others, such as Mudge, Arnold and Earnshaw, who left the chronometer in a form which has since changed relatively little in 100 years.

The Museum Collection includes photographic transparencies showing Harrison's four pioneer marine timekeepers, examples of chronometers by Arnold, Earnshaw and other early and modern makers, together with a collection of exhibits illustrating the various methods which have been employed for overcoming the effect of changes of temperature on the rate of chronometers, and models showing the type of escapement generally employed in chronometers.

338. PHOTOGRAPHS OF HARRISON'S FIRST MARINE TIMEKEEPER.

This is the first of the series of four marine timekeepers designed and constructed by John Harrison between the years 1728 and 1759. It was completed in 1735.

During the 17th century, when long sea voyages had become common, an urgent need was felt by navigators for some means of determining their longitude when at sea, and so pressing had become this need that in 1714 the British Government offered an award of £20,000 for a method of determining longitude at sea, to within an accuracy of 30 miles, at the end of a voyage to the West Indies. It was realised that the problem could be solved by carrying on board ship a reliable timekeeper, but no timekeeper in existence at that period was able to attain anything like the accuracy required. Harrison, however, was convinced that such a machine could be constructed, and he devoted practically his whole life to the work, finally winning the award with his fourth timekeeper.

The first timekeeper is essentially a clock designed to be unaffected by the motion of a ship. It is controlled by two balances which are connected together by a system of wires (effectively a frictionless gearing) which causes them to oscillate always in opposite directions so that the effect of the ship's motion is eliminated. The effect of varying temperature is compensated by varying the effective length of the balance springs, the instrument being the first balance-wheel timekeeper to employ any kind of temperature compensation. The escapement is Harrison's "grasshopper" and the escape wheel is driven directly by the mainsprings through the fusee, there being no remontoire as in Harrison's later timekeepers. Harrison's own "maintaining power" is fitted for keeping the instrument going while it is being wound. The instrument was repaired and put in working order by Lt.-Commander R. T. Gould in 1933, and is now in the National Maritime Museum, Greenwich.

[See "The Marine Chronometer," by R. T. Gould.] Inv. 1936–375, Photo 7868.

339. PHOTOGRAPH OF HARRISON'S SECOND MARINE TIMEKEEPER.

This is the second of the series of four marine timekeepers made by John Harrison between 1728 and 1759, in his efforts to obtain the award of £20,000, which was offered by the British Government in 1714 for a method of determining longitude at sea within an accuracy of 30 miles in a voyage to the West Indies. It was completed in 1739, but was not tried at sea owing to the danger of its being captured by the Spaniards, with whom Great Britain was then at war. The complicated appearance of the instrument is mainly due to

the extensive use of anti-friction devices, friction wheels being used throughout as supports for the bearings and roller teeth of lignum vitæ being employed for the pinions.

To counteract the effect of the ship's rolling, two balances moving in opposite directions are used and are so connected by wires passing over brass arcs that they are virtually geared with one another and move together. The escapement is of the "grasshopper" type, which was invented by Harrison and is described in connection with the Vulliamy clock (Catalogue No. 126) exhibited in the gallery. One pallet arm is mounted on the axis of each balance. The heavy balances move under the control of four helical springs which are subjected to extension, and compensation for change of temperature is obtained by means of a system of four short brass and two long steel rods, which are arranged through four bell crank levers to vary the distribution of tension in the springs. The inner two turns of each spring are coiled in an opposite direction to the remainder and at the junction of the two portions a pointed block is mounted on the spring. This block makes contact with a plate on the end of one of the bell crank levers except during the latter part of each swing.

Each balance weighs about 6·5 lb. and is built up in a rigid girder form with a ball at each end. Owing to its motion being restricted to about 10° at each side of its neutral position it is unnecessary to supply complete friction wheels for its supporting bearings which consequently take the form of short sectors. Axial wires are fitted to prevent end motion of the balances, for although the balance staff is grooved where it engages with the sectors, the arms of the latter are too long to give the necessary rigidity.

There is a remontoire mechanism which is re-wound every 3·75 minutes by the action of the main train of wheels. This remontoire includes two helical springs connected by wires with brass arcs, which are so shaped that a uniform torque is transmitted to the escapement.

The main train includes a fusee and a maintaining power mechanism which is fitted to the pinion of the second wheel. There is also a stop work to prevent overwinding, and the instrument goes 36 hours for each winding. It weighs about 100 lb. and after being out of order about 150 years it was restored to working condition by Lieut.-Commander R. T. Gould in 1924; it is now housed in the National Maritime Museum at Greenwich.

[See "The Marine Chronometer," by R. T. Gould.] Inv. 1936–376, Photos 7870, 3331.

340. PHOTOGRAPH OF HARRISON'S THIRD MARINE TIMEKEEPER.

This instrument is the third of the four marine timekeepers constructed by John Harrison, and was completed in 1757. It was never actually tried at sea, as it was superseded by the fourth timekeeper, which was much smaller, and was originally intended to be a mere auxiliary to the third timekeeper, but proved to be equally accurate.

The third timekeeper is essentially a spring-driven clock controlled by two large balances. These balances are connected together by crossed wires, which cause them to oscillate always in opposite directions, the effect of the ship's motion being thus eliminated.

The main mechanism is mounted between three parallel brass plates, which will be referred to as the front, middle and back plates respectively, while a small extension in front of the front plate contains the motion work. The instrument consists of two main portions—a clock of very simple construction (which will only go for three-quarters of a minute) mounted between the middle and back plates, and a remontoire train, mounted between the front and middle plates, which re-winds this clock every half-minute; the remontoire train is driven by the mainspring, and is normally kept locked by a pivoted detent, discharged every 30 seconds by a circle of pins on the escape-wheel arbor.

Almost every moving portion is mounted on so-called "friction wheels." The balances move through so small an arc that complete friction wheels are unnecessary for their support; these accordingly assume the form of short arcs, mounted at the end of pivoted arms. The pinion rollers, the pallets and most of the bearing surfaces are made of lignum vitæ (a naturally greasy wood) and in consequence of these arrangements no oil whatever is required in any portion of the machine.

The escape wheel is directly driven by the two helical remontoire-springs; these springs exert their pull through two brass wires, running over arcs which are so curved that a uniform torque is always imparted to the escape wheel. The escapement itself is Harrison's "grasshopper," one pallet arm being mounted on the axis of each balance.

The motion of the balances is controlled by a single spiral spring of about $1\frac{1}{2}$ turns. Compensation for variation of temperature is obtained by varying the effective length of this spring by means of a bi-metallic "compensation curb"—the first of its kind ever constructed. This curb is mounted in such a way that both the mean rate of the chronometer and the amount of compensation can be varied at will.

A unique form of adjustment for isochronism is provided. Mounted on the lower balance-wheel axis is a hardened steel cam upon which rests a stirrup which is pulled downwards by a system connected with an adjustable spring. This system gives a torque which opposes that due to the balance-spring, and the shape of the cam is so designed that the combined torque is strictly proportional to the displacement. This device can be seen situated between the middle and back plates.

Harrison's No. 3 timekeeper resembles No. 2 in its general design, its type of escapement and its remontoire arrangement, but differs from it in the type of balance-spring employed, the method of temperature compensation, and the device for securing isochronism.

The machine weighs some 66 lb. and goes for 36 hours at one winding. It was restored to working condition by Lieut.-Commander R. T. Gould in 1924–31, having been out of order for some 160 years, and is now in the National Maritime Museum, Greenwich.

[See The Horological Journal, Vol. 74, p. 166 (1932).] Inv. 1936–377, Photos 7871, 7872.

341. TWO PHOTOGRAPHS OF HARRISON'S FOURTH MARINE TIMEKEEPER.

This is the timekeeper which won the £20,000 prize offered by the British Government for a method of determining a vessel's longitude at sea, to within an accuracy of 30 miles, at the end of a voyage to the West Indies. The instrument was completed in 1759, and in 1761 it was taken to Jamaica and back in H.M.S. "Deptford." On arrival at Jamaica it was found to have erred by no more than five seconds, corresponding to an error in longitude of only 1¼ seconds, or approximately one mile. In a second test in 1764 the instrument was taken to Barbados and back, its total error then being only 54 seconds in five months, while after certain corrections had been applied this error was reduced to 15 seconds.

The fourth timekeeper is much smaller than its predecessors, being only about 5 in. in diameter, but it embodies all Harrison's experience gained with the earlier and larger instruments. It has only a single balance-wheel and the escapement employed is a much improved modification of the verge, while as in the third timekeeper compensation for the effects of change of temperature is obtained by varying the effective length of the balance spring by means of a bi-metallic "compensation curb." An ingenious remontoire is fitted, which is re-wound by the mainspring every 7½ seconds.

Harrison, with this instrument, first showed that it was possible to construct a portable timekeeper which would keep sufficiently accurate time at sea to be of use in determining longitude, and thus solved the problem of "finding the longitude," which had baffled scientists and inventors for over 200 years. The instrument is now preserved in the National Maritime Museum at Greenwich.

[See "The Marine Chronometer," by R. T. Gould.] Inv. 1936–378, Photos 7873, 7875.

342. CHRONOMETER (see Plate VIII). Made by John Arnold and Son. Lent by Messrs. C. Frodsham & Co., Ltd.

This two-day marine chronometer was made about the end of the 18th century. It is mounted in an octagonal wooden box and is fitted with John Arnold's detent escapement which was patented in 1782.

Arnold's escapement is similar in principle to Earnshaw's, which is represented by a large model in an adjacent case (Catalogue No. 356), but, in action, the detent is bent towards the centre of the escape wheel when the latter is unlocked, and it is consequently necessary for the teeth to project upwards. The faces of the teeth are of epicycloidal shape.

The balance spring is made of gold and is of the helical form patented by Arnold in 1775.

Temperature compensation is obtained from the balance, which consists of two bi-metallic arcs of about 90° on the free ends of which adjustable weights are mounted. This arrangement was included in Arnold's patent in 1782.

Maker's No. 63. Inv. 1879–31, Photo 7246.

343. CHRONOMETER. Made by John Arnold and Son. Lent by Samuel Edgcumbe, Esq.

This two-day marine chronometer has John Arnold's detent escapement. It was made about 1800 but was modified at a later date and is now fitted with a compensation balance of a form patented by J. R. Arnold in 1821.

In this balance there is a horizontal bimetallic cross bar, consisting of flat strips of brass and steel at the ends of which are vertical arms carrying weights. The bending of the bimetallic arm due to a rise of temperature causes the weights to approach the centre of the balance. At right angles to the bimetallic bar there is a diametral arm carrying timing screws.

Maker's No. 43/133. Inv. 1917–112.

344. CHRONOMETER. Made by J. R. Arnold. Lent by Lt. J. F. Godwin, R.E.

This small one-day marine chronometer was made during the early part of the 19th century and includes the helical form of balance-spring and the detent escapement patented by John Arnold, the father of J. R. Arnold, in 1775 and 1782 respectively.

The escapement differs but slightly from that used in modern chronometers. In this example the impulse face of the teeth of the escape-wheel are of epicycloidal form and the detent moves towards the centre of the wheel to unlock. In modern chronometers, however,

the escape-wheel teeth have flat faces and the detent moves away from the centre of the wheel to unlock. These latter features were introduced by Earnshaw who, working independently, invented the detent escapement almost simultaneously with Arnold.

Earnshaw's escapement is the form now generally employed for chronometers.

The compensation balance is of the bimetallic-rim type and consists of two arcs made up of strips of brass and steel rigidly attached, the former being on the outside. These two arcs are mounted on a diametral arm and the necessary compensation is arranged by means of two small adjustable weights on the rim of the balance at the free ends of the arcs. Two timing screws are employed and are fitted at the ends of the diametral arm.
Maker's No. 488. Inv. 1929–937.

345. MARINE CHRONOMETER. Made by John R. Arnold, London.

This one-day chronometer was made in the early part of the 19th century and has an Earnshaw detent escapement.

An up-and-down indicator is provided to show when winding is required and this is operated by means of a pinion on the fusee arbor.

A special feature is the provision of an arrangement for winding without having to turn the movement upside down in accordance with the general practice. The winding square is at the side of the dial, on an arbor passing to a wheel at the bottom of the case which, when the winding square is pushed down, engages with a larger wheel squared on to the fusee arbor. Normally the two wheels are out of gear.

The balance and balance spring now fitted are not the original ones.
Maker's No. 532. Inv. 1906–53.

346. MARINE CHRONOMETER. Made by Thomas Earnshaw.

This one-day chronometer was made in the early part of the 19th century and has a detent escapement of the type which was introduced by Earnshaw, about 1782, and is still generally employed in marine chronometers.

The balance is of the form first constructed by Earnshaw, but it has been modified by the addition of a device invented by Sir George Airy about 1871. This consists of a diametral bar carrying springs on the extremities of which small weights are mounted. The latter are kept in close contact with the inside of the rim of the balance, and consequently move inwards or outwards with the rim. They thus virtually form part of the balance weights, but as the bar carrying them can be readily rotated on the balance staff and their distances from the free ends of the half rims thereby varied, it is possible to adjust the balance for temperature compensation without moving the main balance weights.
Maker's No. 705. Inv. 1906–54, Photo 7245.

347. CHRONOMETER. Made by George Margetts, London. Lent by Bruno Roberts, Esq., and Mrs. J. Williamson.

This eight-day marine chronometer has an Earnshaw detent escapement and was made about 1800. It includes Margetts' device for preventing the endstone becoming "pitted" by continual wear. The bottom endstone consists of a rotating agate disc about 0·75 in. diameter, which is mounted on a wheel gearing with the great wheel, the balance pivot bearing on the agate disc at about 0·25 in. from its centre. As a result, the wear on the endstone is distributed along a circle and not confined to one point.

Winding up is effected at the side by means of a toothed wheel, which is at right angles to the fusee and gears with a wheel secured to the fusee body.

An inscription states that this chronometer was made for Captain Sir Thomas Williams, of the Royal Navy. Captain Williams was knighted in 1796 for capturing the French frigade "La Tribune," of 44 guns, when in command of the English frigate "Unicorn," of 32 guns. Maker's No. 59. Inv. 1920–568.

348. CHRONOMETER. Lent by Commodore Sir D. E. Brownrigg, Bart.

This two-day marine chronometer was made by Lewis Recordon, London, about 1800.

It has an Arnold detent escapement but instead of the usual arrangement for marine chronometers with which the balance wheel makes 14,400 single vibrations an hour and the wheel train consequently advances every half second, the balance makes 18,000 single vibrations an hour and the train advances five times in two seconds. The roller is entirely a stone, probably a sapphire.

The movement is fitted with a brass cap of the type formerly used for watch movements. Maker's No. 173. Inv. 1918–187.

349. CHRONOMETER WITH GUILLAUME BALANCE. Made by Paul Ditisheim, 1925.

This chronometer is of a type introduced by Paul Ditisheim in 1921 and is fitted with a Guillaume balance specially designed to give continuous compensation for variations of

temperature. A steel balance-spring is employed, and the balance wheel is of the ordinary cut bimetallic form, but the steel usually employed in the rim is replaced by a special alloy of nickel and steel due to Dr. C. E. Guillaume.

This alloy possesses an expansion co-efficient which varies with temperature, and its properties are such that, combined with brass, it causes the weights of the balance to move inwards more for a rise of temperature than they move outwards for an equal fall, which is the effect desired to compensate exactly for the changing stiffness of the balance-spring. With a balance of this type record results have been obtained in the official trials of watches at the National Physical Laboratory.

[See Proceedings of the Physical Society of London, Vol. 32, pp. 374–404.]

The marine chronometer shown includes other special features. It is designed to carry a centre-seconds-hand and is wound by means of a permanently attached button. The hands are set by means of an external push-pin and wheel, and the escapement portion is mounted in a detachable frame which may be removed and replaced by a duplicate when necessary.

The example shown is provided with a lever escapement but an additional interchangeable frame with a detent escapement, elinvar hairspring, and Ditisheim balance is shown separately.

[See Proceedings of the Physical Society of London, Vol. 35, pp. 261–5 (1923).]

Inv. 1925–193.

350. DETENT ESCAPEMENT WITH ELINVAR HAIRSPRING. Made by Paul Ditisheim, 1925.

Elinvar is an alloy, introduced about 1920 by Dr. C. E. Guillaume in connection with his researches on the properties of nickel-steels. Its modulus of elasticity remains nearly constant over ordinary ranges of temperature and, when employed for the hairspring of a watch or chronometer, it almost dispenses with the necessity of any form of temperature compensation. Such compensation as is necessary can, however, be obtained by adding short bi-metallic blades to an uncut monometallic balance, as in the Ditisheim balance in this example.

The escapement is mounted in a frame which forms an interchangeable portion of the adjacent marine chronometer (Catalogue No. 349).

Two models on a magnified scale of balances employed with the elinvar hairspring are also shown (see Catalogue No. 355).

[See Proceedings of the Physical Society of London, Vol. 35, pp. 261–5.]

Inv. 1925–193.

351. CHRONOMETER DESIGNED FOR EXTREME TEMPERATURES. Lent by Messrs. Thomas Mercer, St. Albans.

This chronometer is fitted with a balance-spring made of "elinvar," an alloy of nickel and steel, together with chromium and other elements, introduced about 1920 by Dr. C. E. Guillaume. The stiffness of an elinvar spring remains very nearly constant over a wide range of temperatures, and hence the rate of a chronometer employing it is only very slightly affected by temperature changes. The balance-wheel of the chronometer exhibited is a solid one, and the small residual temperature effect can be compensated by a short pair of bi-metallic blades.

In 1926 the British Engineering Standards Committee arranged a series of tests of chronometers suitable for use in aircraft. The tests, which were carried out at the National Physical Laboratory, extended over an unusually wide range of temperature from $-20°$ C. to $+50°$ C.

The change of rate of this chronometer was found to be small and remarkably consistent over the whole range of temperature, and the report of the test stated that "if it were found practicable, by further fine adjustment of the bi-metallic affixes, to compensate for the small temperature coefficient, it would appear possible to make the daily rate come within the extremely fine limits, $\pm$ 1 or 2 seconds, at all temperatures."

[See The Horological Journal, Vol. 69, pp. 121, 139 and 165 (1927).] Inv. 1931–716.

COMPENSATION BALANCES

352. COMPENSATION BALANCES FOR MARINE CHRONOMETERS. Lent by Messrs. Thomas Mercer, St. Albans.

1. Balance of modified Earnshaw type. For use with a steel or palladium balance-spring. One pair of bi-metallic arms carries a pair of relatively heavy fixed weights; the second pair carries two lighter screws whose position can be varied to vary the amount of compensation given.

2. Balance with Poole's auxiliary compensation. A discontinuous compensation for use

with a steel balance-spring. Each short fixed arm carries a screw which at normal temperatures just touches the outside of the bi-metallic arm at a point about ¼ in. from the fixed end of the latter. At lower temperatures only the arc of the bi-metallic arm beyond this screw can move outwards; at higher temperatures the whole of the arm from its fixed end moves inwards, giving a greater movement of the weight for a given change of temperature.

3. Balance with Kullberg's auxiliary compensation. A discontinuous compensation, for use with a steel spring. Two small extra bi-metallic arms are fitted; these move inwards for a rise of temperature, but cannot move outwards for a fall, as they bear up against the points of a pair of screws carried on the main bi-metallic arms.

4. Balance with Mercer's auxiliary compensation. Similar in principle to (3), a pair of auxiliary arms being fitted which can move inwards from their normal position but are prevented from moving outwards.

5. Guillaume or "integral" balance. A balance with four equal bi-metallic arms, each made of brass together with Guillaume's special nickel-steel alloy whose expansion coefficient is greater at low temperatures than at higher ones. Gives very close and continuous compensation for the change of stiffness of a steel balance-spring.

6. Uncut invar balance with bi-metallic affixes. For use with an "elinvar" balance-spring, whose stiffness is almost independent of temperature. The size of the invar balance is also practically unaffected by temperature changes, and the small residual primary effects are compensated by a short pair of bi-metallic blades which are continuously in action.

7. Uncut brass balance with bi-metallic affixes. Similar to (6) but made of brass instead of invar. Since brass expands a little with rise of temperature slightly more compensation is required, and the compensating weights are slightly heavier than in (6).

8. Balance with sliding bi-metallic affixes. For use with an "elinvar" balance-spring. The sliding affixes enable the amount of compensation given to be readily adjusted.

[See "The Marine Chronometer," by R. T. Gould.] Inv. 1929–69 to 76, Photo 7241.

353. LOSEBY'S COMPENSATION BALANCES. Lent by E. T. Loseby, Esq.

Balances of this form were invented by E. T. Loseby about 1843, and were designed to eliminate the middle temperature error. They were employed in chronometers which occupied high positions in the lists for the Greenwich trials during the period 1845–1852.

In the ordinary form of bi-metallic compensation balance the ends of the rims bend approximately equal amounts inward or outward for equal rises or falls of temperature respectively, but the conditions for continuous compensation require that such outward movement should be less than the corresponding inward movement. It is consequently possible to adjust such a balance for two extreme temperatures only, and at intermediate temperatures there is an error known as the middle temperature error. Many secondary compensation devices have been employed to eliminate or to reduce this error, the action of some being continuous and that of others discontinuous. Loseby's balance is an example of a continuous compensation.

Superimposed upon a balance of the ordinary bi-metallic form there are two small bulbs with tubes containing mercury as in a thermometer. These are mounted on the free ends of the rims and their tubes are so curved that for a rise of temperature the end of the mercury moves more towards the centre of the balance than it would move away from the centre for an equal fall of temperature, and it is thus possible to arrange for continuous compensation. To prevent the mercury threads breaking, a little air is left in the tubes when they are sealed.

Five modifications are shown. In No. 1 the tube is attached to the weight used for the ordinary compensation, and in No. 2 it is detached. No. 3 is similar to No. 2 with the addition of position screws, and No. 4 is a form in which the tube could be adapted to chronometer balances of the ordinary type. No. 5 is a magnified drawing which illustrates the application to pocket chronometers and watches, and Nos. 6 and 7 show tubes in progress of manufacture and finished. Inv. 1884–75, Photo 7251.

354. KULLBERG'S FLAT-RIM BALANCE. Presented by V. Kullberg, Esq.

This balance was invented by Victor Kullberg about 1860, and was designed to avoid the middle temperature error, which is present in the ordinary form of bi-metallic compensation balance. Chronometers with this balance headed the lists in the trials at the Royal Observatory, Greenwich, in 1864, 1872, and 1873.

The arm and the rims are flat and made up of brass and steel. In the arm the brass is at the top, but in the rims it is at the bottom. A rise of temperature causes the ends of the arm to bend downwards and the free ends of the rims to bend upwards and in so doing to move slightly inwards. The balance weights are mounted on short pillars above the rim and consequently the amount by which they move inward for a certain rise of temperature is greater than the amount they would move outward for an equal fall in temperature, a condition which is necessary to secure continuous compensation.

Inv. 1926–251, Photo 7274.

355. DITISHEIM COMPENSATION BALANCES. (Scale about 4:1.) Presented by Paul Ditisheim.

These models represent a type of compensation balance designed about 1923 by Paul Ditisheim, for use with elinvar hairsprings. Each consist of an uncut monometallic ring with the addition of short bi-metallic blades to effect the small amount of temperature compensation required.

One model has projecting radial poising screws as in the ordinary compensation balance, but in the form represented by the other model the poising screws are placed entirely in the rim. This feature is not shown in the model, but it is included in the balance of the adjacent escapement with elinvar hairspring (Catalogue No. 350). This reduces the air friction and lessens the variations in timekeeping which follow changes in the atmospheric pressure. For the same purpose the compensating blades are placed in recesses in the rim of the balance, and it should be noted that improvements in methods of eliminating the effects of changes of temperature have resulted in increased attention being given to errors arising from barometric disturbances.

One advantage of the uncut balance is the absence of changes of shape arising from centrifugal forces, the differences between which in long and short arcs of vibration lead to complication in the adjustment of the hairspring. Inv. 1925–194, Photo 7259.

ESCAPEMENT MODELS

356. CHRONOMETER ESCAPEMENT. Made and presented by A. W. Curzon, Esq.

This model shows, on a magnified scale, the form of detent escapement invented by Thomas Earnshaw about 1782, which still remains the standard form for use in marine chronometers.

The escape-wheel teeth are locked by a locking pallet carried on a bar or detent which is mounted on the end of a strip spring. Attached to the detent on the side nearer the escape-wheel there is a fine strip spring which slightly projects beyond the end of the detent. Rollers or discs on the balance carry an unlocking pallet and an impulse pallet. The former engages with the fine spring and when moving in one direction encounters little resistance as the spring bends along its full length and is easily pushed away. On the return motion, however, the fine spring is pushed against the detent and the short portion of this spring which projects beyond the end is stiff enough to cause the detent to be moved by the action of the unlocking pallet. This motion is sufficient to release the escape-wheel and, as the latter advances, one of its teeth engages with the impulse pallet and gives an impulse to the balance, such impulse being given on alternate vibrations only.

In an actual chronometer the locking, unlocking, and impulse pallets consist of jewels and the fine strip spring is made of gold.

For demonstration purposes the model is fitted with graduated scales whereby the angles over which the various operations take place can be read and, in addition, provision is made for showing the effects of altering the distances between the various elements of the mechanism. Inv. 1926–165, Photo 162/48.

357. CHRONOMETER ESCAPEMENT. Made by Messrs. E. Dent and Co.

This model, for use with a projecting lantern, represents the detent chronometer escapement which was invented by Thomas Earnshaw about 1782 and is still generally used in marine chronometers. Inv. 1883–67.

For chronometer watches and watches with temperature compensation, see Catalogue Nos. 265 to 276.

VI. JAPANESE CLOCKS

MODERN TIME-RECKONING in equal hours was not introduced in Japan until 1870. Previously to that date, Japanese clocks were designed to indicate "temporal" hours, *i.e.*, to divide the periods of daylight and darkness each into six divisions. The "hour" intervals were numbered 9, 8, 7, 6, 5, 4 respectively from midday to midnight, and in the same sequence again from midnight to midday. Japanese striking clocks were therefore designed to strike the hours according to this system; at the half-hours a single stroke was sounded and, at the alternate half-hours, two strokes. The sequence of strokes given by a Japanese striking clock was therefore, 9, 1, 8, 2, 7, 1, etc.

Japanese clocks may be divided into three main classes—"Lantern", "Bracket" and "Pillar" clocks. The Museum collection includes examples of all three types together with other Japanese table clocks.

LANTERN CLOCKS

358. JAPANESE "LANTERN" CLOCK (see Plate IX). Lent by P. L. Harrison, Esq.

This clock indicates the time on the old Japanese system in which the periods of daylight and darkness are each divided into six intervals. On this system day and night hours are of different lengths, and in this clock two separate escapements, each complete with crown-wheel, verge and foliot balance, are provided, one being in use during the daytime and the other at night. The change-over at dawn and dusk is automatically carried out by the striking mechanism.

Two crown wheels on one arbor are driven by the going train of wheels, and as the clock is striking the hour corresponding to dawn or dusk a pin in the count-wheel of the striking train engages with a pinion of six leaves and turns it through one-sixth of a revolution. On the same axis as this pinion are two triangular cams, and these cams move levers which engage with the bottom pivots of the verges, one verge being allowed to fall into its working position while the other one is lifted from engagement with its crown wheel.

To allow for the variation in the length of the days and nights the weights on the foliot balances are shifted along the arms at intervals of 15 days.

The clock has a single hand mounted on a rotating inner dial which is tapped with a number of holes, into any one of which the pin for discharging the alarm can be screwed.

The clock strikes the "hours" in the usual Japanese sequence of 9, 8, 7, 6, 5, 4 from midnight to noon and again from noon to midnight, and gives a single stroke each half "hour." Inv. 1937–889, Photo 195/38.

359. JAPANESE "LANTERN" CLOCK. Lent by P. L. Harrison, Esq.

This clock is provided with a special striking arrangement whereby the last two strokes occur in quick time to indicate that the clock has finished striking, thus reproducing mechanically the manner in which the time signals were formerly struck by hand.

To obtain this special action, there is an extra striking hammer, operated by a series of pins mounted on the count wheel, which gives the final strokes.

In other respects the clock is similar in general to the clock with iron movement exhibited adjacently (Catalogue No. 358), except that it has brass plates and wheels, and a dial rotating behind a fixed pointer. It was probably constructed early in the 19th century. Inv. 1930–660, Photo 7257.

360. JAPANESE "LANTERN" CLOCK. Lent by P. L. Harrison, Esq.

This clock, which probably dates from the early 19th century, is controlled by a balance wheel and spring, and the balance wheel is provided with adjustable weights for regulating its period of oscillation. The clock strikes on the usual Japanese system and is also fitted with an alarm. The dial rotates behind a fixed pointer and the hour-marks are adjustable in a sliding ring in the dial to allow for the variation in the length of the hours at different seasons.

Two small square apertures below the dial show characters which, when combined, indicate the day of the sexagenary period, a system of reckoning in cycles of 60 which, according to Hoffmann's "Japanese Grammar," was introduced into Japan from China in A.D. 602, and was employed for counting months and days as well as years. At the back

of the dial plate there are two wheels with 12 and 10 teeth respectively; the former, on the left, is marked with 12 characters representing the signs of the zodiac and the other with 10 characters representing the five "elements," wood, fire, earth, metal and water, each taken in two forms. These wheels are advanced one tooth each day by means of a pin mounted on the back of the rotating dial, and the period of 60 days, showing 60 different combinations, is completed when one wheel has made five and the other six rotations.

Inv. 1937–891.

BRACKET CLOCKS

361. JAPANESE "BRACKET" CLOCK (see Plate IX). Lent by P. L. Harrison, Esq.

This striking clock has a rotating dial provided with adjustable indicators for showing the time on the old Japanese system in which the periods of daylight and of darkness are each divided into six intervals.

A fixed hand is employed and the dial rotates in a clockwise direction once a day. The characters indicating midday and midnight are fixed at diametrically opposite positions on the dial, but in order to allow for the difference in the lengths of the day and night "hours" at different seasons of the year, each remaining hour-mark is mounted on a small plate which slides in a grooved ring in the dial.

The clock is spring-driven and controlled by a verge escapement and "bob" pendulum. It strikes on the usual Japanese system, the sequence of strokes from midnight to noon being 9, 1, 8, 2, 7, 1, 6, 2, 5, 1, 4, 2. Inv. 1930–663, Photo 7260.

362. JAPANESE "BRACKET" CLOCK. Presented by Sir Robert Hadfield, F.R.S.

This striking clock, probably made about the middle of the 19th century, indicates time on the usual Japanese system in which the periods of daylight and darkness are each divided into six intervals. It is similar in general to the adjacent clock (Catalogue No. 361), but it is controlled by a balance wheel and spring and the dial rotates in an anti-clockwise direction.

The date is shown, on the Japanese sexagenary system, by means of the characters appearing in the two small square apertures below the dial.

As the original hand was missing, the one shown was added in the Museum.

Inv. 1930–190, Photo 4278.

363. JAPANESE BRACKET CLOCK. Lent by D. E. Flinn, Esq.

This clock resembles the adjacent example (Catalogue No. 362) in most respects, but differs from it in being provided with indicators for the whole "hours" only, and in striking also at the whole "hours" only, the sequence of strokes being 9, 8, 7, 6, 5, 4, corresponding with the numbering of the Japanese "hours." Inv. 1952–181.

PILLAR CLOCKS

364. JAPANESE CLOCK. Lent by P. L. Harrison, Esq.

This 19th-century clock is of the scale type, in which the time is indicated by the vertical position of the weight which drives the clock. The weight carries an index moving over a graduated scale, which covers the period of one complete day and night.

To allow for the unequal time periods employed during the days and the nights at different parts of the year, the graduated scale is changed monthly.

This clock is controlled by a verge escapement employing a "bob" pendulum.

Inv. 1930–662, Photo 7247.

365. JAPANESE CLOCK. Lent by P. L. Harrison, Esq.

In this striking clock of the scale type, the striking movement is employed as a weight to drive the going train, and the time is indicated by the vertical position of an index mounted on the striking movement.

This index moves over a vertical scale which is provided with adjustable indicators to allow for the variations at different parts of the year of the time intervals measured. The striking mechanism is driven by a spring which is wound up daily by means of a key. A locking-plate striking mechanism is employed which is actuated by a series of pins projecting inwards from the adjustable time indicators.

A verge escapement with a balance wheel and balance spring is employed.

Inv. 1930–661, Photo 7249.

366. JAPANESE CLOCK.

This clock resembles the adjacent ones (Catalogue Nos. 364 and 365), the time being indicated by the height of the driving weight, which carries an index moving over a graduated scale. In this clock, however, the scales for all the months of the year are combined upon a single plate, and the index connected with the weight is movable horizontally across its bar so as to bring it opposite to the scale of hours for the appropriate month.

The variation in length of the Japanese day and night "hours" is well shown by this plate. It will be seen that in mid-winter the day and night "hours" are of almost equal length, while in midsummer the day hours are some two-and-a-third times as long as the night hours. It must, therefore, have been customary to count a considerable period of twilight at each end of the day as belonging to the day, so that in mid-winter "day" and "night" would each last for some 12 European hours, while at midsummer "day" would last almost 17 European hours and "night" a little over seven.

Inv. 1928–721, Photo 7240.

367. JAPANESE "PILLAR" CLOCK. Lent by S. Peter, Esq.

This clock is of special interest in being fitted with a "pirouette" or geared balance wheel.

The verge carries a toothed sector which gears with a pinion coaxial with the balance wheel.

This device was employed by Huygens in his pioneer watch with balance spring made in 1675; it has the advantage that the balance can have a large arc of swing, but it introduces considerable friction which is detrimental to good timekeeping.

The design of Japanese clocks owes a good deal to Dutch influence, and it is possible that the clock exhibited, which is probably about 150 years old, can be regarded as a descendant of the first Huygens watch. Inv. 1950–11, Photo 99/50.

TABLE CLOCKS

368. JAPANESE CLOCK WITH PORCELAIN CASE. Lent by P. L. Harrison, Esq.

In this type of Japanese clock the mainspring drives the timekeeping mechanism through a cord which it unwinds from a cylindrical drum, and the hour-indicator is attached to a point on this cord. The hour-marks themselves are adjustable in a groove to allow for the different lengths of the hours at different seasons of the year according to the old Japanese system of time-reckoning. The indicator traverses the whole length of the scale in a day and night and is then drawn back again as the mainspring is wound up.

The timekeeping is controlled by a verge escapement with balance and spring.

The porcelain case bears pictures of the animals with which the various hours of the day and night were associated on the Japanese system.

Inv. 1937–888, Photos 191/38, 192/38.

369. JAPANESE TABLE CLOCK. Lent by P. L. Harrison, Esq.

This is a transitional type of clock in which the dial carries a set of arabic numerals as well as the usual Japanese hour-signs. The clock is driven by a mainspring through a fusee and is controlled by a verge escapement with balance and spring. It indicates equal hours according to the modern European system.

It is provided with an adjustable alarm released by an arm falling off a snail.

Inv. 1937–892, Photo 196/38.

VII. ELECTRIC CLOCKS

EVER SINCE the discovery early in the 19th century of the magnetic effects of electric currents inventors have tried various ways in which electricity can be used in the measurement of time. Electric currents have been employed chiefly for two purposes—to supply the power necessary to drive a clock, and to transmit synchronising signals from one "master" clock to a number of distant clocks, so that all may indicate the same time.

Electrically driven independent clocks can be divided into three main classes:

(1) Clocks in which the pendulum is kept swinging by forces due to electromagnets.

(2) Clocks in which the impulse to the pendulum is given by the fall of a gravity arm or the release of a spring which is afterwards restored to its original position by an electromagnet—these may be termed "electric gravity escapements".

(3) Mechanical clocks in which the driving weight or spring is re-wound at intervals by some form of electric motor.

Various methods of distant control have been used. In the earliest ones, currents were sent out from a master clock every second, so that the pendulums of the subsidiary clocks were kept swinging in unison with that of the master clock. This method has now been superseded by others in which the currents are sent out less frequently.

In a system which has been widely used, the master clock sends out a current every minute or half minute which energises the electromagnet of each distant "impulse dial" and so moves its hands through the space of one minute or half a minute. In other systems the subsidiary clocks are independent spring-driven clocks whose hands are automatically set right every hour by a current impulse transmitted from the master clock. In a still further system each subsidiary clock is driven by a synchronous electric motor operated from alternating current the frequency of which is kept constant.

EARLY SYSTEMS OF ELECTRIC PROPULSION AND SYNCHRONISATION

370. BAIN'S ELECTRICALLY DRIVEN CLOCK.

This clock, patented by Alexander Bain in 1845–7, is one of the early electric clocks, and dates from only a few years after the invention of the electric telegraph. The pendulum is maintained in motion by the pull of an electromagnet energised every alternate swing, and drives the clock wheelwork by means of a light arm and hook engaging with a ratchet wheel.

Bain was the first to maintain a pendulum in motion by means of electromagnetic impulses instead of by mechanical impulses transmitted through an escapement, as in ordinary clocks; the clock exhibited is one of his later designs.

The bottom of the pendulum carries a coil which swings over two bar magnets with their N. poles facing each other and separated by a small gap. When a current passes through the coil it is attracted by one magnet and repelled by the other, so that it receives an impulse. Electrical contacts are made every alternate swing by a brass slider impelled by a pin on the pendulum. This slider runs in two grooves, one of which is all of metal and the other partly of metal and partly of insulating material, and contact is made only when both ends of the slider are on metal. Contact occurs first near the end of a swing to the right and lasts during most of the ensuing swing to the left, the pendulum being impelled to the left during this time.

[See "Electrical Timekeeping," by F. Hope-Jones.] Inv. 1909–135, Photos 7273, 7272.

371. WHEATSTONE IMPULSE DIAL. Lent by King's College, London.

In 1840 Wheatstone published a paper in the Proceedings of the Royal Society entitled "Description of the Electro-magnetic Clock" in which he gave an account of various ways in which an electric master-clock could be made to send electrical signals and so propel a series of distant repeaters or "impulse dials."

The dial here exhibited corresponds to one of those described in this paper, and is to be driven by impulses of current arriving once per second.

When such a current impulse passes through the electromagnet of the dial, its armature is attracted, against the pressure of a spring, and afterwards released. The two pallets attached to the sliding armature engage with the opposite sides of a double-sided crown wheel, and a single to-and-fro motion advances this wheel through the pitch of one tooth. The seconds-hand of the dial is coaxial with this crown wheel, and so is correspondingly advanced through the space of one second. The minute and hour hands are driven from the seconds-hand by suitable reduction gearing.

[See Royal Society's Proceedings, Vol. 4, p. 249 (1840).] Inv. 1949–303.

372. WHEATSTONE MASTER-CLOCK (see Plate X). Presented by G. W. Grabham, Esq.

This is an example of the type of master-clock which was being constructed by Wheatstone's company, the British Telegraph Manufacturing Company, about 1870.

The pendulum of a powerful mechanical clock carries a coil which swings over a pair of horseshoe magnets. The movements of the coil in the magnetic field generates a current which is transmitted to the dial movements in circuit with the coil. The pendulum thus behaves as a dynamo generating alternating current at a frequency of one cycle per second, and the dial movements are effectively synchronous motors driven by this current. The system, although it eliminates troubles due to faulty contacts, is bad from the timekeeping point of view, since the interference with the free motion of the pendulum is very great.

Accordingly, the master-clock is provided with a synchronising mechanism, of a type patented by J. M. A. Stroh, in which it receives a synchronising signal from an accurate clock every two hours. If it is slow, the subsidiary pendulum linked with the main one is effectively shortened, so that the pendulums will be speeded up; if fast, the pendulums are correspondingly slowed during the ensuing period.

[See British Patent Specification No. 3028 of 1869.] Inv. 1950–216, Photo 159/51.

373. WHEATSTONE IMPULSE DIAL. Presented by G. W. Grabham, Esq.

This is designed for use with the adjacent master-clock (Catalogue No. 372), which sends out pulses of current, generated from the swinging pendulum, twice per second, in alternate directions.

The movement of the dial consists of three flat magnets mounted on the same axis of rotation, one magnet lying within a coil carrying the current while the others lie outside it. The magnets are arranged so that the north-seeking pole of one lies above the south-seeking pole of the other, so that there is no resultant force on them from the earth's magnetic field, while the field from the coil urges them in the same direction: the magnet system is, in fact, astatic. In operation the magnets make one rotation per second about their vertical axis, and so drive the minute and hour hands of the impulse dial through suitable reduction gearing.

Each dial movement is, in fact, an electric synchronous motor, operating from the alternating current at one cycle per second generated by the pendulum of the master-clock.

Inv. 1949–181.

374. ELECTRICALLY CONTROLLED CLOCK.

This clock illustrates a method of synchronisation introduced in 1858 by Mr. R. L. Jones, in which the pendulums of a number of ordinary weight-driven mechanical clocks are made to swing in unison with that of a "master" clock by means of electromagnetic impulses due to electric currents sent out every second from the master-clock. With this, which was one of the first systems of distant control of a number of clocks to be introduced in this country, the individual clocks still continue to go even if the electrical circuit is accidentally broken, though they are then no longer synchronised.

The pendulum of the subsidiary clock carries a coil which swings over a system of two magnets with their N. poles facing, as in the adjacent Bain clock (Catalogue No. 370). Currents from the master-clock, which is of the Bain type, pass through these coils every second; if the pendulum is late the forces on the coil tend to accelerate it, if early to retard it, so that it is kept synchronous with that of the master-clock.

The example exhibited, which was made about 1880 for the General Post Office, is not actually under control but is working independently.

[See British Patent Specification No. 702 of 1857.] Inv. 1913–580.

375. ELECTRICALLY DRIVEN PENDULUM. Made and presented by Messrs J. Ritchie and Son, Edinburgh.

The method of maintaining this pendulum is similar to that employed in the Bain clock which is exhibited in this Gallery (see Catalogue No. 370). With this pendulum, however, the electrical contacts which control the timing of the impulses are not derived from the pendulum itself, as in the Bain clock, but are made by a "master" clock of the Bain type. The pendulum is accordingly made to swing in unison with that of this master-clock.

This method of synchronisation has been used by Messrs. J. Ritchie and Son, and should be compared with that of Mr. R. L. Jones, illustrated in another exhibit in this Gallery (see Catalogue No. 374), in which the actual drive of the pendulum is by ordinary clock mechanism, the electrical impulses serving for synchronisation only.

[See British Patent Specification No. 2,078 of 1872.] Inv. 1913–562.

376. ELECTRICALLY DRIVEN PENDULUM. Made and presented by Messrs. J. Ritchie and Son, Edinburgh.

This pendulum system, patented by Mr. F. J. Ritchie in 1872, is in principle exactly similar to the adjacent one (Catalogue No. 375), being maintained by electro-magnetic impulses due to currents received every second from a master-clock of the Bain type. It differs, however, from other types in that the pendulum is loaded above its point of support. This pendulum, although beating seconds, need not be as long as the usual type, and so can be accommodated in a smaller space.

The controlling arrangement is in duplicate, the pendulum carrying two coils each of which move over a system of two magnets as in the usual Bain type of clock. A short pendulum of this type, loaded above its point of support, is more liable than the usual type to interference by frictional resistances, and for this reason is not normally used in clocks. In this case it can be safely applied since the pendulum need not be accurately timed, as it is controlled by the master-clock.

[See British Patent Specification No. 2,078 of 1872.] Inv. 1913–563.

377. DIAL MOVEMENT. Made and presented by Messrs. J. Ritchie and Son, Edinburgh.

This device, patented by Mr. F. J. Ritchie in 1872, shows a method by which an electrically-maintained pendulum is made to drive the handwork of a clock.

It is for use with pendulums similar to those of adjacent exhibits (Catalogue Nos. 375 and 376), which are maintained in motion by currents transmitted every second from a master-clock.

The device consists of a reversed escapement with two gravity arms. These arms are lifted by the pendulum, and in falling back again they drive the escape wheel.

[See British Patent Specification No. 2,078 of 1872.] Inv. 1913–564.

ELECTRICALLY MAINTAINED PENDULUMS

378. FÉRY'S ELECTRICALLY DRIVEN PENDULUM. Lent by Prof. Charles Féry.

In this device, invented and patented by Professor Charles Féry of Paris in 1907, a pendulum receives impulses from an electro-magnet every swing, but the contact-making is done by a subsidiary pendulum driven from the main pendulum by electromagnetic attraction. The main pendulum is thus free in so far as it makes no material contacts, but the interference with its motion due to contact-making, though indirect, is still very considerable.

The bob of the main pendulum consists of a horse-shoe magnet, one pole of which threads a fixed coil, while the other passes through a copper ring carried on the subsidiary pendulum. Eddy currents are set up in the copper ring, and the forces between these and the magnet of the main pendulum tend to reduce relative motion, so that the subsidiary pendulum is kept swinging. The left-hand contact makes the circuit through the fixed coil which gives the impulse to the main pendulum, while the right-hand contact can be used to drive or control a subsidiary clock or system of dials.

The coil is made of high resistance in order to reduce the relative importance of variations of contact resistance.

[See British Patent Specification No. 23,416 of 1907.] Inv. 1913–568.

379. BULLE ELECTRIC CLOCK. Presented by The British Horo-Electric, Ltd., London.

This is an electrically driven clock invented by Professor Marcel Moulin and M. Favre-Bulle about 1920.

The pendulum carries a solenoid moving over a curved bar magnet with consequent poles, north seeking in the middle and south poles at the ends. A current from a cell

passes through the coil during part of alternate swings, and the interaction between this current and the magnet supplies the impulse necessary to maintain the pendulum in vibration.

A pin near the top of the pendulum engages with a forked lever and completes the electric circuit, one side of the fork consisting of conducting metal and the other of insulating fibre. By means of a pawl the forked lever propels a crown ratchet wheel which is connected with the hands by worm gearing.

The motion of the coil in the magnetic field generates an electro-motive force in opposition to that of the cell and consequently the larger the arc of vibration and the quicker the motion of the coil at the middle of its swing, the smaller the current passing from the driving cell.

For the purposes of eliminating the circular error of the pendulum and controlling the arc of vibration, one end of a short helical spring is attached to the pendulum rod, the other end of the spring being fixed on the centre line below the pendulum suspension.

Inv. 1922–675.

380. ELECTRICALLY DRIVEN CLOCK. Made by M. Hipp, Neuchatel. Presented by Prof. Silvanus P. Thompson, F.R.S.

This clock is fitted with the "butterfly escapement" which was invented by Matthaüs Hipp in 1842. With this escapement an electrical contact is made when the arc of vibration of the pendulum falls below a certain amount, and an impulse is consequently given to the pendulum.

The pendulum carries an armature and swings above an electro-magnet, while pivoted to the bottom of the pendulum there is a small trailer which slides over a small notched block. When the vibrations are large enough the trailer moves clear of the block at each swing, but when the vibrations fall below a certain amount the trailer does not leave the block and engages with a notch as the pendulum returns. This causes a spring on which the block is mounted to be depressed and thus closes the circuit through the electro-magnet, which then attracts the armature fixed to the bottom of the pendulum and so imparts the necessary impulse to the pendulum. Inv. 1913–567, Photo 7244.

See also Catalogue No. 407.

381. "EUREKA" ELECTRICALLY DRIVEN CLOCK. Lent by Gustave Kutnow, Esq.

This clock, invented in 1906 by T. B. Powers and G. and H. Kutnow, and made by The Eureka Clock Company, Ltd., differs from most other electric clocks in that it is controlled by a balance-wheel instead of by a pendulum, but resembles other types in principle in that the oscillating system—in this case the balance-wheel—makes a contact and receives an impulse from an electro-magnet near the middle of each swing. In this clock, as in others, variations of battery voltage affect the magnitude of the impulse and hence the arc of swing, and the force required to make contact is supplied by the balance-wheel.

The balance-wheel carries an electromagnet which, when energised, is attracted to an armature fixed in the base of the clock. A pin on the balance-wheel makes contact near the middle of the balance swing with a blade; the electromagnet is then energised and an impulse given to the wheel.

In the clock exhibited the contact blade has been renewed.

[See British Patent Specification No. 14,614 of 1906.]

Inv. 1913–570, Photos 184/49, 213/49.

382. "CLINKER" MAINS-DRIVEN NON-SYNCHRONOUS ELECTRIC CLOCK. Lent by Hillyard T. Stott, Esq.

In this clock, invented by R. C. Clinker of the B.T.H. Co. in 1932, impulses to the pendulum are given every swing by means of an electromagnet excited from the A.C. mains supply. The electromagnet is "tuned" to the frequency of the supply by means of a parallel capacitor, and both are fed from the mains through a small series capacitor.

As the pendulum approaches its central position, its iron armature approaches the fixed electromagnet, altering its effective inductance, and throwing its circuit out of tune. The current in the circuit is therefore reduced and the pull on the armature decreased accordingly. It can be shown by fairly simple electrical theory that both these effects have a small time-lag, so that the pull on the pendulum is slightly less as it moves away from its central position than on its approach to that position on its downward swing.

The pendulum therefore receives a net impulse every swing.

The pendulum operates the clock dial mechanism through a one-sided crutch and a simple pawl-and-ratchet mechanism.

For proper operation, the pendulum requires a fairly large arc of swing, and the clock cannot be considered one of high precision, but its accuracy is sufficient for normal domestic purposes.

The power consumption is extremely small.

[See Institution of Electrical Engineers, Students' Quarterly Journal, Vol. 4, No. 16, p. 163 (June, 1934).]

Inv. 1947–114.

ELECTRIC GRAVITY ESCAPEMENTS

383. FROMENT'S ELECTRICALLY DRIVEN PENDULUM. Presented by F. Hope-Jones, Esq.

This method of maintaining a pendulum was invented by Froment in 1854. During part of a swing to the left an arm attached to the pendulum pushes against a spring, while for a rather longer portion of the return swing the spring pushes the arm, a balance of energy being thus available to keep the pendulum in motion. The impulse is imparted near the end of a swing, but its magnitude is independent of the voltage of the battery, and the force which drives the pendulum also presses the contacts together, thus making a reliable contact.

As the pendulum swings to the left, a screw on an arm attached to it makes contact with a light spring. Normally this spring rests on one end of a movable armature, pivoted near its centre, but, when contact is made, the other end of the armature is pulled up by the electromagnet, so that when the spring returns with the pendulum it can pass to a lower position than that from which it started, thus delivering some of its stored-up energy to the pendulum. At the break of the contact the armature falls back and the spring is restored to its original position.

Although this arrangement is similar to a gravity escapement in that the impulse is constant and independent of the driving force, the break is too slow and the contact of too long duration for efficient working.

[See "Electrical Timekeeping," by F. Hope-Jones.] Inv. 1912–234.

384. ELECTRICALLY MAINTAINED FREE BALANCE. Presented by the Telephone Manufacturing Co. Ltd.

In this escapement, originally patented by Mr. Sydney J. Smith in 1931–2, the balance-wheel oscillates under the influence of a helical balance-spring. One end of the spring is attached to the balance and the other end is pinned to a pivoted arm. The oscillations of the balance are maintained by the movements of this arm, which alter the effective pull of the balance-spring.

An extension of the arm referred to above carries a light wheel which can bear on one or other of two flat springs. As the wheel approaches the end of its movement in one direction it presses one of the springs and makes an electric contact. This contact closes the circuit of an electro-magnet which, in addition to driving the recording mechanism, moves the backstop of the contact-spring inwards, so that the wheel in executing its return motion is followed by the contact-spring for a somewhat greater distance than that over which it pushed the spring on the outward motion.

Energy is therefore transferred from the flat spring to the wheel, and eventually to the balance through the balance-spring, at every swing. It will be noticed that the balance-wheel has no "unlocking" duty to perform, and that it receives its impulse through the medium of the balance-spring.

The counting mechanism is of the type invented by Mr. S. J. Smith for the "Princeps" master-clock, which can be seen in an adjacent impulse dial movement (Catalogue No. 409). The motion of each backstop click breaks the electrical circuit, so that the current pulses required are brief.

[See British Patent Specifications Nos. 362,518 and 370,956.]
Inv. 1947–99, Photo 60/50.

385. REGULATOR EMPLOYING THE MEATH-BOWELL ELECTRIC GRAVITY ESCAPEMENT. Presented by the Earl of Meath.

This escapement was due to the collaboration of the 13th Earl of Meath with G. B. Bowell, and was devised as the result of a series of experiments carried out over the years 1933–38. It may be classified as an electric gravity escapement, for it is driven by a small electric motor operated from a 1½-volt dry cell, and the impulse to the pendulum is a "gravity" one, i.e., an impulse of fixed amount given by the fall of a gravity arm through a constant distance. The impulse is given almost symmetrically about the zero position and the impulse arc is about one-half the total arc. Unlocking occurs symmetrically about zero, and the unlocking arc is about one-sixth of the whole arc.

As the pendulum swings to the right, it engages with the right-hand pivoted arm and releases a rotating arm driven from the continuously running electric motor through a slipping friction clutch. During the pendulum's excursion to the right, a cam coaxial with the rotating arm lifts the left-hand impulse arm; the pendulum picks this up early in its leftward excursion and on its return receives a gravity impulse, since the pallet on the impulse arm is then opposite the flat part of the cam, and the arm can therefore move further to the right. During the pendulum's excursion to the right the cam again restores the gravity arm to its higher position to the left, ready for the next impulse, and is then temporarily locked until released by the pendulum.

The dial-work of the clock is driven by gearing from the cam shaft, which is permitted by the pendulum to make one revolution each double swing, i.e., every two seconds. The rate of rotation of the electric motor must be kept within certain limits, but with this proviso it does not affect the rate of the clock. Inv. 1948–314.

386. FREE PENDULUM CLOCK MAINTAINED BY ROLLING BALLS. Presented by Captain E. E. Craig.

In this clock, invented and made by Captain Craig, the pendulum receives its impulses from a pair of light steel balls which roll down two short ramps attached to the pendulum by horizontal arms. It is termed a "free pendulum clock" because the pendulum has no unlocking duty to perform and swings freely except while it is actually receiving its impulse, and for the small fraction of a second during which the ball rests against the edge of the ramp before rolling down it.

The cycle of operations during a complete double swing of the pendulum is as follows:

After the right-hand ball has imparted its impulse to the pendulum, it rolls away towards the back of the clock movement and operates a trigger which allows the right-hand mercury switch to tilt over and close its circuit. The right-hand electro-magnet operates, and the resulting movement throws the right-hand ball upwards to its highest position, and at the same time releases the small catch holding the left-hand ball. This ball then rolls a small fraction of an inch until it rests against the edge of the left-hand pendulum ramp, which is then on its downward travel.

As the ramp descends the ball is able to roll down it, impart its impulse, and then roll away towards the back of the clock movement.

The second half of the cycle is similar, but with "right" and "left" interchanged.

Inv. 1946–193, Photo 133/49.

387. CAMPICHE MASTER-CLOCK. Presented by F. Hope-Jones, Esq.

In this electrically driven clock, patented by M. A. and H. Campiche in 1893–9, the pendulum rotates a count-wheel which makes an electrical contact every minute; an impulse is then given to the pendulum by means of a flat spring.

This is believed to be the first type of clock in which a count-wheel is used in this way. The brief bursts of current can be used to drive a series of impulse dials.

The count-wheel carries a pin which is pressed against two blades every minute and so makes the contact. An armature is then attracted to an electro-magnet and one end of a long flat spring is pressed against the pendulum by a connecting lever, so imparting an impulse.

The energy required for making contact is taken directly from the pendulum.

[See British Patent Specifications No. 8,830 of 1893 and No. 10,393 of 1899.]

Inv. 1912–231.

388. SYNCHRONOME MASTER-CLOCK. Presented by F. Hope-Jones, Esq.

This is an example of the type of electrical master-clock developed and patented by Mr. F. Hope-Jones in 1905–7 and since widely used. It is intended to transmit electrical impulses every half minute to a number of distant "impulse dials," and its design is such that the transmission of the impulses does not interfere with the accurate timekeeping of the master-clock. The actual clock exhibited is a relatively modern one, but it differs in no essential feature from the 1907 model.

The pendulum beats seconds, and mounted upon it there is a light hinged arm which is provided with a jewelled pin which at every swing to the right engages with a "count-wheel" of 15 teeth and turns it through the width of one tooth (at each swing to the left the jewel rides lightly over a tooth of the wheel). The wheel therefore makes a complete revolution every half minute. The wheel carries a vane which once every revolution engages with a catch and releases a hinged gravity arm carrying a roller. This roller then falls upon an inclined face mounted upon the pendulum and, as it rolls down the face, imparts a mechanical impulse to the pendulum. Immediately afterwards a tailpiece on the gravity arm meets a contact mounted upon the end of the armature of an electro-magnet and closes a circuit containing the coils of the electro-magnet and also of the electro-magnets of the connected dial mechanisms. The electro-magnet of the master-clock is therefore energised, pressing the contacts together and pushing the gravity arm upward. The armature soon meets a stop, but the momentum of the gravity arm causes it to continue in motion upward until it is again locked upon its catch. The contact is thus sharply broken when the armature reaches its stop.

The method employed ensures an impulse of invariable amount being given to the pendulum every half minute, and gives a decisive "make" of electrical contact, a firm pressure throughout its duration, and a sharp "break," so that a single well-defined electrical impulse is sent out to the dials.

Arrangements are provided whereby the master-clock and its connected dials can all be retarded or advanced together. For this purpose the jewelled hook attached to the pendulum can be made either to ride clear of the count-wheel altogether so that the pendulum

swings idly, or can be pushed up so that it engages with the catch of the gravity arm and so releases the arm and transmits an impulse every two seconds.

The Synchronome clock exhibited is serving as a "slave" to the adjacent Shortt free pendulum clock (Catalogue No. 392) and is synchronised by means of the Shortt synchroniser (see Catalogue No. 393).

[See "Electrical Timekeeping," by F. Hope-Jones.] Inv. 1935–127.

389. SYNCHRONOME DIAL. Presented by F. Hope-Jones, Esq.

This shows the impulse dial mechanism employed in the Synchronome system of electric clocks.

It consists of an electro-magnet through which a current is passed every half minute by the action of the master-clock. The electro-magnet attracts an armature which is mounted on a lever carrying a pawl, and when the current ceases to flow, the armature moves away from the electro-magnet, under the action of a spring, and the pawl moves a wheel of 120 teeth, carrying the minute wheel, through the space of one tooth.

A click is mounted on an arm which carries a pin engaging with a semi-circular notch in the lever carrying the pawl, and above the latter there is a stop. This arrangement prevents the wheel being moved more than one tooth at a time, and also ensures that the wheel is positively controlled throughout the operations. Inv. 1935–127.

390. BARTRUM'S FREE PENDULUM CLOCK. Presented by Mrs. K. I. Bartrum.

This clock, first described by C. O. Bartrum of Hampstead in 1917, embodies the principle of the free pendulum and slave clock first employed by Rudd in 1899 (see Catalogue No. 131). It is probably the first clock of this type to work reliably.

The free pendulum, on the left, swings freely between impulses, and receives an impulse of a fraction of a second's duration every minute; after the impulse it transmits a synchronising signal to the slave clock, on the right. At the end of the ensuing minute the slave clock releases the next impulse to the free pendulum.

The impulse imparted to the free pendulum is a gravity one of constant amount, and the lever which applies the impulse is released by an electro-magnet operated by the slave clock. As the impulse arm falls away after giving the impulse, it makes an electric contact which transmits a synchronising signal to the slave clock and also actuates an electro-magnet which restores the gravity arm to its rest position. The slave clock then measures out the ensuing period of just under 60 seconds before it releases the free pendulum's impulse arm for the next impulse. As described below, the nature of the synchronising action is such that any error arising in the slave is rocked with decreasing amplitude until it has disappeared and the two pendulums are exactly synchronised again. The synchroniser has the great theoretical merit of correcting both the rate and phase of the slave. The slave clock itself, on the right, is a weight-driven timepiece with dead-beat escapement.

The details of the impulsing and synchronising system are as follows:

A light arm attached to the slave clock's pendulum engages with a count-wheel and rotates it once per minute. A pin on the count-wheel passes between two contact springs and makes electrical contact for a fraction of a second once per minute at a time dictated by the slave pendulum. This contact makes an electrical circuit, A, which releases the impulse arm of the free pendulum and allows the jewelled wheel upon it to fall upon the horizontal surface of the impulse pallet of the free pendulum. If the slave clock is early, the jewelled wheel will have a relatively long run on this surface, occupying a correspondingly long time; if late, the run and the time occupied will both be short. Circuit A also includes an electro-magnet which releases the weighted "timing wheel" of the synchroniser mounted near the slave pendulum, and allows it to begin to rotate.

If the two pendulums are exactly in the correct phase, the timing wheel will have made exactly one-quarter of a revolution when the synchronising signal arrives from the master-clock. The star-wheel mounted just below the timing wheel will not then be rotated, since the small chopper will pass between the two regulating pallets. If the slave is late, the timing wheel will have made just under one-quarter of a turn when the synchronising signal arrives, and the left-hand pallet will be engaged by the chopper, rotating the star-wheel through one tooth in an anti-clockwise direction; if the slave is early, the timing wheel will make just over one-quarter of a turn, and the star-wheel will be rotated by the right-hand pallet through one tooth in a clockwise direction.

Coaxial with the star-wheel is a drum on which is wound a thread attached to the lower end of a helical spring coupled to the slave pendulum. It will be seen that an anti-clockwise rotation of the star-wheel will increase the tension of the spring and make the slave clock relatively fast during the ensuing minute; a clockwise rotation will reduce the spring tension and cause the slave to run relatively slowly.

The net result of these arrangements is to rock the error and rate of the slave, and any backlash in the mechanism would cause the amplitude of the rocking to increase progressively. To meet this difficulty, a supplementary rating spring is fitted which introduces considerable negative backlash, which more than cancels out any natural backlash and causes the amplitude of the rocking error to decrease progressively until it is practically

wiped out. The negative backlash is applied through an arm coaxial with the star-wheel and drum, and friction-tight on the shaft. The movement of the arm is limited by two stops, and it moves only when the correction applied to the slave changes sign, i.e., at the point at which natural backlash would occur.

[See Proceedings of the Physical Society of London, Vol. 29, p. 120 (1917).]

Inv. 1939–310, Photos 211/49, 212/49.

391. BARTRUM'S BAROMETRIC COMPENSATOR. Presented by Mrs. K. I. Bartrum.

Variations of barometric pressure affect the time of swing of a pendulum in two ways. High pressure, leading to high air density, buoys up the pendulum, reducing the effective value of gravity and so slowing the pendulum; the high density also increases the frictional drag and produces a further slowing effect. The first effect can be calculated fairly accurately, and for a pendulum with brass bob amounts to about 1/5th second per day for each 1 inch rise of the mercury barometer; the second effect depends upon the shape of the pendulum bob, but for a cylindrical bob is roughly equal to the first, so that the total error is about 2/5th sec./day for 1 inch rise of pressure. Bartrum's compensator, first described by him in 1929, is intended to compensate this effect.

It consists of a pile of vacuum boxes (as employed in an aneroid barograph). The bottom of the pile is fixed to the pendulum rod, while the top carries a weight. A rise of barometer causes the boxes to contract under the increased pressure and so to lower the weight. If the compensator is mounted well above the mid-point of the pendulum rod, lowering the weight will speed it up, and the amount of speeding can be adjusted to compensate the slowing described above. The actual movement of the weight is about 1/40th inch for 1 inch change of barometric pressure.

[See "The Practical Watch and Clock Maker", 15th March, 1929, and "Journal of the British Astronomical Association," vol. 44, No. 6 (1934).] Inv. 1948–340.

392. SHORTT FREE PENDULUM CLOCK. Made by The Synchronome Co., Ltd.

This type of clock was perfected by Mr. W. H. Shortt, working in conjunction with Mr. F. Hope-Jones and the Synchronome Company, in 1921–4. It forms the practical realisation of the principle of the free pendulum and slave clock, illustrated by Rudd's pioneer free pendulum clock (Catalogue No. 131) and Bartrum's free pendulum clock (Catalogue No. 390) which are exhibited nearby.

The best mechanical timekeeper known is a pendulum swinging freely under gravity, but in order to convert such a pendulum into a practical clock the pendulum must be sustained in motion, so that its oscillations do not die down, and the swings must be counted. In ordinary clocks the sustaining and counting functions are both carried out by the escapement and clock mechanism, but the free motion of the pendulum is considerably interfered with thereby, with a consequent loss of accuracy in timekeeping.

In the Shortt clock the two functions are carried out by a subsidiary or "slave" clock: a standard Synchronome clock, which in this case is mounted to the right of the free pendulum (see Catalogue No. 388). Every half minute the slave clock transmits a short electrical impulse to the free pendulum, energising an electro-magnet which releases a catch and allows a jewel mounted on a light arm to fall upon a small wheel mounted on the free pendulum. As the jewel rolls off the wheel it imparts a light impulse to the free pendulum, this impulse being all that is required to make good the energy lost by the free pendulum during the preceding half minute. After imparting the impulse the light arm releases a heavier arm which falls into an electrical contact and is restored to its original position by an electro-magnet; the same current which operates this electro-magnet passes through the operating coil of the Shortt synchroniser (see Catalogue No. 393) on the slave clock. The slave clock is thus corrected so that it will release the gravity arm at the correct moment at the end of the next half minute.

The free pendulum, therefore, swings entirely freely except for the fraction of a second every half minute during which it is receiving its impulse. The impulse given is strictly constant in amount and is given symmetrically at the mid-point of the swing.

In an observatory Shortt clock the free pendulum swings in a copper case pumped out to a low pressure and the whole is mounted in a basement room whose temperature is kept as constant as possible. Under these conditions the Shortt clock has proved itself capable of measuring time continuously to an accuracy of a few thousandths of a second per day, equivalent to about one second per year.

Shortt clocks were the standard timekeepers at Greenwich Observatory from 1925 to 1942, when they were superseded by quartz crystal clocks.

[See "Electrical Timekeeping," by F. Hope-Jones.] Inv. 1935–126, Photos 7626, 7627.

393. SHORTT "HIT-AND-MISS" SYNCHRONISER. Made by the Synchronome Co., Ltd.

This synchroniser, patented by Mr. W. H. Shortt in 1921, enables the Shortt free pendulum clock on the left (Catalogue No. 392) to synchronise the Synchronome clock (Catalogue No. 388), which is serving as a "slave" to the free pendulum.

The pendulum of the slave clock is fitted with a vertical leaf spring which normally swings just clear of a projection on the armature of the synchronising electro-magnet. If, however, the pendulum of the slave is late the armature will be pulled down just before the spring is passing it, the two will engage, and the bending of the spring will apply a force to the pendulum which quickens the ensuing half-swing by one two-hundredth of a second. The rate of the slave clock is so adjusted that this process effects approximately twice the amount of correction needed, so that at the expiry of the next 30 seconds the slave pendulum will still be ahead of time and its spring will therefore be just past the tip of the synchroniser at the moment of operation. At the end of a further 30 seconds, however, synchronisation will again be effected. "Hitting" and "missing" thus occur roughly at alternate half minutes.

[See British Patent Specification No. 187,814.] Inv. 1935–127.

See also Catalogue No. 403.

SELF-WOUND CLOCKS

394. SELF-WINDING ELECTRIC CLOCK. Lent by Capt. F. E. Dyke Acland.

This clock was invented by Chesters H. Pond, of Brooklyn, New York, in 1881. It is driven by a small rotary electric motor which winds up a spring hourly. Inv. 1912–241.

395. SELF-WINDING ELECTRIC CLOCK. Lent by the Aron Electricity Meter Co., Ltd.

In this clock, which was invented by Dr. Hermann Aron of Berlin in 1892–4, a light tumbler switch is operated by the running down of the clock train; an armature then rewinds the driving spring and replaces the switch.

This self-winding action was primarily designed to operate the modern Aron electricity meters, several types of which are exhibited in the Electric Power section of the Museum. Inv. 1912–239.

396. HOEFT MÖLLER SELF-WINDING CLOCK. Lent by Richard Freytag, Esq.

The clock, patented by Max Hoeft of Berlin in 1899, is a mechanical clock, the spring of which is periodically rewound by an electro-magnet. The re-winding mechanism is illustrated in the accompanying diagram.

The armature of the electro-magnet, pivoted at its centre, tends to rotate clockwise on account of the tension in a helical spring, and as it slowly rotates it drives the clock through a pawl and ratchet wheel. When the armature has turned to the position shown by the broken lines in the diagram exhibited, an electrical contact is made and the electro-magnet is excited. The armature is accordingly attracted by the electro-magnet and rotates sharply counter-clockwise, extending the spring, and the electrical contact is broken.

The arrangements for making contact can be seen with the aid of the diagram exhibited. Inv. 1913–579.

397. SELF-WINDING ELECTRIC CLOCK. Presented by F. Hope-Jones, Esq.

In this clock, made in 1898 by the National Self-Winding Clock Co., U.S.A., the contact for closing the circuit which excites the operating electro-magnet is made by mercury in a small sealed tube.

The electro-magnet is laminated and winds up both "going" and "striking" trains.

See also Catalogue Nos. 400 *and* 416. Inv. 1912–236.

MINUTE OR HALF-MINUTE IMPULSE SYNCHRONISED SYSTEMS

398. HIPP IMPULSE DIAL. Presented by F. Hope-Jones, Esq.

In this impulse dial mechanism, introduced by M. Hipp of Neuchatel about 1860, a pivoted and magnetised armature is made by currents from a master-clock to turn through a large angle, swinging alternately from one pole of an electro-magnet to the other. This rocking motion is converted into a rotary motion of the hands by means of a reversed verge escapement.

The master-clock sends out a current each minute, the current being alternately in opposite directions. The armature, being permanently magnetised, is attracted alternately to one or the other pole of the electro-magnet.

The purpose of this design is to ensure that the hands of the dial shall not move through more than one minute for each impulse from the master-clock. If the contact of this clock is faulty, each impulse may consist of several small bursts of current, and with a

dial of the step-by-step type, each of these would be recorded by the dial as a separate impulse. With a dial of the Hipp type, where successive impulses must be in opposite directions in order to be recorded, this type of error cannot occur.

[See "Electrical Timekeeping," by F. Hope-Jones.] Inv. 1912–228, Photo 7250.

399. RECLUS IMPULSE DIAL. Lent by Sir W. C. Leng & Co., Ltd., Sheffield.

This electrical impulse dial movement was patented by Victor Reclus of Paris in 1886.

It is believed to be the first in which the wheel is locked at every stage in the cycle of operations by the use of two clicks only.

With this locking device it is impossible for the momentum of the hands to cause them to over-run and so to move through the space of two teeth for a single impulse.

[See British Patent Specification No. 12,491 of 1886.] Inv. 1912–238.

400. "SYNCHRONOME" SELF-WINDING CLOCK. Presented by F. Hope-Jones, Esq.

This self-winding clock, made by the inventors, Messrs. F. Hope-Jones and G. B. Bowell, in 1895, is an ordinary mechanical clock driven by a weighted lever which is lifted every half-minute by an electro-magnet. For contact-making it employs the "Synchronome" switch, a type now widely used in master-clocks (see Catalogue No. 388), the essential features of which are that the contacts are pressed together by the force which re-winds the clock and not by forces derived from the pendulum or wheel-work, and that momentum is made use of to secure a quick break. The clock was designed for use as a master-clock to drive a number of impulse dials.

The clock is driven by a gravity lever acting upon a pawl and ratchet wheel, and every half-minute the lever as it falls makes contact with the end of a hinged armature. The circuit of an electro-magnet is then closed and the armature is immediately pressed against the weighted lever, reinforcing the contact. The lever is thrown up, and as the armature comes against a stop the lever continues in motion under its own momentum, the contact being thus sharply broken.

The two features—a decisive "make" and a sharp "break" of contact—ensure that a single well-defined current impulse shall be sent out to the dials.

[See British Patent Specification No. 1587 of 1895.] Inv. 1912–235, Photo 7256.

401. PALMER'S IMPULSE DIAL. Presented by F. Hope-Jones, Esq.

This impulse dial of the step-by-step type was patented by W. E. Palmer in 1902. It is so designed that the ratchet wheel is locked at all stages of the motion, so that it cannot move through more than the pitch of a single tooth for a single impulse.

On the end of a lever carrying the armature there is a pawl and also a short arm provided with a hole which embraces a pin on a pivoted triangle. The ratchet wheel is normally locked by the arbor of this triangle, but when the pawl moves forward to propel the wheel the triangle rotates so that a notch in its arbor permits a tooth to pass. One corner of the triangle locks against a plate at one extremity of its rotation, so limiting the possible travel of the pawl to the right.

[See British Patent Specification No. 10,541 of 1902.] Inv. 1912–229.

402. MORSE IMPULSE DIAL. Presented by F. Hope-Jones, Esq.

This impulse dial was patented by J. S. Morse in 1903.

Between the poles of an electro-magnet there is a pivoted armature which is normally kept in an inclined position by the action of a weight. When the circuit is closed the armature is drawn into the line joining the poles of the electro-magnet and this partial rotation is made to propel a ratchet wheel by means of a pawl. The pawl is so mounted on the armature that the wheel cannot be moved through more than one tooth at a time.

[See British Patent Specification No. 10,071 of 1903.] Inv. 1912–230.

403. PULSYNETIC TIME TRANSMITTER. Made and presented by Messrs. Gent & Co., Ltd., Leicester.

This electrical time transmitter or master-clock is a modern version of the type patented by I. H. Parsons and A. E. J. Ball in 1904–7. It is designed to transmit electrical impulses every half minute to a number of dials connected in series, all the dials being moved through half a minute at the same time.

It consists of a seconds pendulum carrying a pawl which engages with a count wheel of 15 teeth and pushes the wheel through the space of a tooth every alternate swing. One tooth of the wheel is more indented than the others and when the pawl engages with this deep tooth, the end of the lever on which the pawl is mounted engages with a stirrup catch and releases a gravity lever. This lever carries a roller which imparts an impulse to the pendulum by engaging with an inclined face.

The gravity lever carries a contact maker which, when the lever falls, completes an

electrical circuit passing through all the connected dials and also through an electro-magnet which, when energised, attracts an armature and restores the gravity lever to its original position.

By means of a cord, acting through a pin, the end of the lever carrying the pawl can be so depressed that it engages with the stirrup catch every alternate swing. Impulses are then given to the dials every two seconds and, when slow, they can thus be brought to the correct time. Inv. 1951–288.

404. MODERN GENT IMPULSE DIAL. Presented by Gent & Co., Ltd., Leicester. Inv. 1951–275.

405. PULSYNETIC IMPULSE DIAL. Made and presented by Messrs. Gent & Co., Ltd., Leicester.

This shows the form of impulse dial mechanism employed in connection with the adjacent Pulsynetic electrical time transmitter (Catalogue No. 403).

It consists of a wheel of 120 teeth, which carries the minute hand and is advanced through the space of one tooth, every half minute, by means of a pawl actuated by the armature of an electro-magnet which receives currents every half minute from the master-clock.

As in other modern impulse dials the arrangements are such that the wheel cannot be advanced through more than one tooth each occasion. Inv. 1913–167.

406. WARNING BELL. Made and presented by Messrs. Gent & Co., Ltd., Leicester.

This device can be employed in connection with the Pulsynetic system of electric clocks to indicate when the electric batteries of the circuit need attention or renewal.

The duration of the currents transmitted by the adjacent master-clock (Catalogue No. 403) depends upon the time required to restore its gravity lever to its usual position, and this time will be longer as the batteries get weaker.

An electric bell is included in the circuit and is struck when the circuit is closed for a long enough period. This occurs only when the batteries are failing, as when they are at full strength the circuit is broken before the striker touches the bell. Inv. 1913–168.

407. ELECTRIC TURRET CLOCK. Made and presented by Messrs. Gent & Co., Ltd., Leicester.

This movement, patented by Messrs. I. H. Parsons and A. E. J. Ball in 1907, is designed for use in turret clocks which have their hands exposed to the weather, and may thus require a variable force for their propulsion. On account of its method of operation it is known as a "waiting-train" movement. The hands are driven by an electrically-maintained pendulum and are automatically set right every half minute by a signal from a master-clock of the type of Catalogue No. 403. The hands move through the space of a half-minute in about 27 seconds, and are then disconnected from the driving pendulum and so remain at rest until the connection is restored by the half-minute signal from the master-clock. The clock has two independent electrical circuits: one which maintains the pendulum in motion, and one which re-connects the hands to the driving mechanism every half minute.

The pendulum is driven by the method invented originally by Hipp (see Catalogue No. 380), in which it receives an impulse whenever its arc falls below a predetermined value. The pendulum carries a small hinged piece or "trailer" which moves over a notched piece mounted on a strip spring. With a full arc of swing the trailer moves free of the notch, but when the arc becomes less the trailer does not clear the notch at the end of a swing, and on the return swing the end of the trailer depresses the notch with the strip spring upon it, and closes a circuit through an electro-magnet situated on the right. When energised this electro-magnet attracts an armature which imparts an impulse by striking a projection on the pendulum.

A pawl attached to the pendulum engages with a ratchet wheel and so drives the hands through worm gearing. The length of the pendulum is such that this ratchet wheel rotates once in about 27 seconds, and at the end of each revolution a pin on the wheel lifts an arm which raises the pawl and puts it out of action until the lever is released by an electro-magnet when the half-minute signal arrives from the master-clock.

The movement exhibited is controlled by the Pulsynetic time transmitter on the adjacent wall (Catalogue No. 403).

[See British Patent Specification No. 20,878 of 1907.] Inv. 1913–195, Photo 8233.

408. "REFLEX" PENDULUM CONTROL. Made and lent by Messrs. Gent & Co., Ltd., Leicester.

By means of this device, patented in 1921 by Hubbard, Parsons and Ball, an ordinary pendulum clock can be put under the control of an electric "master" clock and made to keep exact time with it.

When a system of electrical impulse dials is installed in a factory, it is desirable that the

workmen's time registers (which are usually driven by pendulum clocks) should be operated from the same system, and the "Reflex" controlling device was designed so that this could be done with a minimum of alteration to the register. The device is fitted directly to the pendulum of the register to be controlled, and no alteration to the clock mechanism is necessary.

The clock to be controlled is arranged to have a slight losing rate, but is automatically set right every half minute by a signal from the master-clock. The losing rate need not be more than 2 minutes in 24 hours, so that even if the electrical circuit accidentally fails the time registers will not be seriously in error.

The device consists of two parts—a flat spring clipped to the pendulum rod, and a rack which is momentarily raised by an electro-magnet when the half-minute signal from the master-clock arrives; when the rack is lifted it engages with the spring. The rack does not impart an impulse to the pendulum, but merely serves as a stop against which the pendulum strikes at the end of its swing to the left.

If the pendulum were keeping exact time it would be at rest at the moment of raising of the rack, and would not be affected by its presence. When, however, the clock is losing slightly, the pendulum will not have quite completed its swing to the left when the rack is raised, and will accordingly rebound from the rack. It will, therefore, return to its mid-position sooner than it would have done if not interfered with, and the clock is thus effectively put forward a small amount every half minute and so made to keep exact time with the controlling master-clock.

[See British Patent Specification No. 167,060, also No. 160,988.] Inv. 1921–376.

409. IMPULSE DIAL MOVEMENT. Lent by the Telephone Manufacturing Co., Ltd.

This movement is designed for operation by a master-clock which sends out a brief pulse of current every half minute; it is of a type patented by Major C. E. Prince in 1925 in which a pallet mounted on a pivoted lever carrying an armature engages alternately with the teeth of two wheels which are in mesh.

When the pulse of current from the master-clock passes through the electro-magnet, the armature is attracted and the pallet moves across from the right-hand to the left-hand wheel, advancing it through the space of half a tooth. When the current ceases, the armature returns under the action of its spring and the pallet engages again with the right-hand wheel, advancing it through the space of half a tooth, the wheels thus advancing one whole tooth for each half-minute impulse.

The movement is locked in all positions.

[See British Patent Specification No. 277,499.] Inv. 1938–333.

410. IMPULSE DIAL MOVEMENT FOR PUBLIC DIALS. Lent by the Telephone Manufacturing Co., Ltd.

This movement is designed for operation by means of pulses of electric current transmitted every half minute from a master-clock, and is intended to drive the hands of a public dial which are exposed to the wind and weather.

It is of a type patented by S. J. Smith in 1928 in which the operating and backstop clicks are electro-magnetically controlled. The armature rotates through a large angle at each impulse and the operating ratchet wheel has only eight teeth. On account of the worm drive, which is irreversible, no amount of force applied to the hands by wind or snow can move them backwards or forwards.

[See British Patent Specification No. 297,891.] Inv. 1938–334.

411. ELECTRIC MASTER-CLOCK. Lent by I.B.M. United Kingdom, Ltd.

In the International Superelectric "supervised" system of electric time indicating and recording the master-clock is a mechanical clock with dead-beat escapement which is electrically wound from the mains. The system has been developed mainly for use in controlling the Company's Time Recorders (an example of which is exhibited in a neighbouring showcase) but it is of course used as well for controlling impulse dials or secondary clocks.

Each minute the master-clock releases an electric impulse to the secondary clocks and recorders which it controls, and in addition the clock sends out every hour a series of impulses which check or "supervise" the accuracy of the secondary instruments, stepping up any which may have missed an impulse and therefore be behind the master-clock, while those which for any reason may have got ahead await a signal to proceed again at the hour. It is not expected that this "supervising" action will often be necessary, but it serves as an additional hourly check on the accuracy of the controlled instruments.

The system is operated entirely from the mains supply, A.C. or D.C., but even if on any occasion the mains supply should fail for a period the master-clock will continue to go, as it has a 12-hour reserve of power. When the electrical supply is resumed, a series of impulses is sent out which steps the dials up until they again show the same time as the master-clock.

Fuller details of the "supervising" action are given in the label describing the secondary clocks. Inv. 1951–178.

412. **RELAY CABINET.** Lent by I.B.M. United Kingdom, Ltd.

The impulse contact in the master-clock does not deal with the current required for the whole system, but is connected with the coil of a relay, so that the contacts in the master-clock have to break only the current of a few milliamps necessary to operate this relay. This method ensures long life to the impulse contacts, the full current for operating the secondary clocks and recorders being dealt with by the relay contacts, which may carry as much as five amps. Inv. 1951–179.

413. AUTOMATICALLY "SUPERVISED" SECONDARY CLOCKS. Lent by I.B.M. United Kingdom, Ltd.

The hands on the secondary clocks of the International Superelectric "supervised" system are driven by a locked rachet-and-pawl mechanism, the pawl being driven by a rotor which oscillates between the pole pieces of an electro-magnet.

All secondary units are connected up with three wires—"operating" wires (A) and (B) and a "common return" (C). Each secondary unit is provided with a selector switch which automatically connects the coil of the driving magnet to the proper one of the two "operating" wires, as described below. Impulses are transmitted along the wires from the master-clock through the relay cabinet.

For each of the first 50 minutes of each hour the impulse is transmitted along both operating wires, and the selector switch is in such a position that it connects the magnet to the (A) wire. From the 50th to the 59th minute, impulses are transmitted along the (A) wire only. When the secondary unit indicates the 59th minute the selector automatically switches over to the (B) wire. If the unit happens to be ahead of the master-clock it then receives no further impulses, and is therefore held up, until the 60th minute, when impulses are resumed on both wires.

Between the 59th and the 60th minute a series of 15 extra impulses is transmitted along the (A) wire. These will not affect the secondary unit if it is correct or ahead, for the selector switch will have operated, disconnecting the dial magnet from the (A) wire. But if it is behind the master-clock these extra impulses will move it on until it indicates the 59th minute, when the selector switch operates as before, disconnecting it from the (A) wire; it then awaits the resumption of normal minute signals along the (B) wire at the 60th minute. The selector switch returns to the (A) position after the 64th minute, and the cycle of operations is then complete.

The selector switch operates between impulses, so that the contacts of this switch will never spark. Inv. 1951–180.

414. MASTER CHRONOMETERS AND TIME DISTRIBUTING PANEL EMPLOYED IN S.S. "QUEEN MARY." Photographs lent by Messrs. Thomas Mercer, St. Albans.

Systems of electric clocks under unified control are particularly useful for ocean-going liners, in which "ship's time" has to be changed daily to allow for the ship's change of longitude. In the s.s. "Queen Mary" over 600 clocks located throughout the ship are controlled by the master chronometers through the time distributing panel shown in the photographs.

In the upper portion of the cabinet two master chronometers are mounted, one being in use and the other kept going as a "stand-by." Each chronometer makes a brief electrical contact every half minute which energises the relay mounted below it.

In the bottom of the cabinet the advancing and retarding mechanisms are mounted. The advancing mechanism causes all the dials controlled by the chronometer to be advanced together when necessary, while the retarding mechanism cuts them all out of circuit for the required number of minutes.

The dial mounted in the middle of the door of the cabinet serves as a "repeater," indicating the same "ship's time" shown by all the other dials on the ship.

See also Catalogue Nos. 387 *and* 388. Inv. 1936–325.

SYSTEMS OF HOURLY SYNCHRONISATION

415. **ELECTRICALLY CORRECTED CLOCK.** Presented by the Imperial Institute.

This exhibit illustrates a method of controlling a number of clocks which was patented by J. A. Lund in 1876 and was used on the Victorian railways in 1892. In this method the hands of an ordinary mechanical clock are corrected every hour by a signal transmitted from a master-clock.

The device for correcting the hands is mounted at the top of and in front of the dial; it consists of two pivoted arms attached to the armature of an electro-magnet. Exactly at the hour the signal arrives from the master-clock, the armature is pulled down, and the two arms close together, scissors-like, grasping the minute-hand and forcing it to the central position.

[See British Patent Specification No. 3,924 of 1876.] Inv. 1909–474, Photo 7275.

416. SELF-WINDING CLOCK WITH HANDS AUTOMATICALLY CORRECTED. Lent by the Metropolitan District Railway Co.

This clock, made by the Self Winding Clock Company of New York, is of the type now used on some of London's Underground railways, and is a self-winding clock, the hands of which are automatically set right every hour by a signal from a master-clock. It has two independent electrical circuits, one for the self-winding mechanism and one for the correcting mechanism.

The self-winding mechanism is a modification of that invented by Pond. In Pond's clock, an electrical contact was made every hour, and the spring was then re-wound by an ordinary rotary electric motor; in the modified clock the contact is made more frequently and the spring is re-wound by a device similar to an electric bell, the vibratory motion winding up the spring by means of a pawl and ratchet wheel.

The mechanism for automatically correcting the hands is illustrated in the accompanying diagram. A disc carrying two small projections is coaxial with the minute-hand. Exactly at the hour a current from a master-clock is sent through an electro-magnet and its armature is attracted and moves up. This causes two claws to engage with the projections on the minute wheel and so force it and the minute-hand to the correct position.

Except for a short period before and after the hour the rotating system is locked by means of a separate simple system. Inv. 1913–581.

SYNCHRONOUS MOTOR CLOCKS

417. TELECHRON ELECTRIC TIMEKEEPER. Made and lent by the Warren Telechron Co., Ashland, Mass., U.S.A.

This electric clock, patented by H. E. Warren in 1918–24, consists of a small synchronous electric motor which is driven by an alternating-current electric light supply and the timekeeping depends upon the maintenance of a constant frequency at the generating station.

The motor has a bi-polar field magnet which is energised by a coil connected by a plug with the supply circuit. Shading coils are carried on the pole pieces, the effect of these being to produce a rotating magnetic field, and a disc-shaped rotor is employed which rotates in exact synchronism with the rotating field. The rotor is connected by gearing with the clock hands, and the rotor and gearing are contained in an enclosed casing which includes an oil bath.

At the generating station there is an independent standard clock mounted coaxially with a Telechron clock and the frequency of the current is so controlled that the two clocks are kept in agreement.

An indicator is provided to draw attention to any interruption of the current supply. This consists of a disc which is coloured red and white and is connected with a small armature mounted on pivots above the pole pieces. Normally one end of the armature is so attracted that only a white portion of the disc is visible through a hole in the dial, but when the current is interrupted the weight of the armature, which is not balanced, moves the system to show a red portion of the disc. The indicator remains at red until it is reset by hand.

The example shown is for use on a supply at 110 volts and a frequency of 60 cycles per second (which is the standard frequency employed in the U.S.A.); it consumes 2 watts. Inv. 1927–987.

418. "SYNCLOCK" SYNCHRONOUS ELECTRIC CLOCK. Made and presented by Everett, Edgcumbe & Co., Ltd.

In this type of electrical clock the hands are directly driven through reduction gearing by a synchronous alternating-current motor, so that instead of counting swings of a pendulum the clock counts alternations of a current. The accuracy of its timekeeping depends therefore entirely on the steadiness with which the frequency of the supply is kept constant.

Many power stations now maintain the frequency of their alternating-current supply so carefully constant with the aid of a standard clock that a synchronous clock such as a "Synclock" will, when connected to this supply and once set right, never be in error by more than a few seconds.

As the clock is self-starting, any temporary interruption of the supply will cause it to be in error subsequently, and so an indicator is fitted to show if any such interruption has occurred. This indicator is similar to that fitted to the "Telechron" timekeeper (Catalogue No. 417).

The "Synclock" exhibited is operated from a 220-volt, 50-cycle supply and consumes about 4 watts. The motor, which is of the "Warren" type, makes 50 revolutions per second, and in order to reduce wear the whole system of rotor and gearing is enclosed in an oil-bath. This system is shown sectioned in a neighbouring exhibit (Catalogue No. 419). Inv. 1931–516.

419. SECTIONED MOVEMENT OF "SYNCLOCK." Made and presented by Everett, Edgcumbe & Co., Ltd.

This exhibit shows the mechanism of a "Synclock" in which the casing which is normally sealed and filled with oil has been cut away to show the rotor and gearing.

The electric motor is of the "Warren" synchronous type. This motor has a laminated field magnet which has four poles. One pair of diametrically opposite poles is provided with thick copper rings, and when the magnet is excited with alternating current the eddy currents set up in these rings modify the field of the pole-pieces in such a way that a rotating magnetic field is produced in the gap, and the steel armature disc is dragged round in this field, making one complete revolution in a double alternation of current.

In an ordinary "Synclock" the motor is geared down so that the minute-hand arbor makes one complete revolution per hour when the motor is fed with 50-cycle alternating-current. In the sectioned movement shown, however, some of the gearing is omitted and a hand is fitted which makes one revolution per second. Inv. 1931–517.

420. COMPARISON CLOCK FOR POWER STATIONS.

This type of instrument is used in modern power-stations in order to keep a check on the average frequency of the alternating-current so that synchronous clocks connected to the supply will show correct time. It consists of a combination of a standard clock and a synchronous clock, arranged to indicate on the same dial so that they may easily be compared.

The inner rotating dial is driven by a synchronous motor and indicates the so-called "frequency time" shown by all synchronous clocks connected to the supply, while the seconds-hand is driven from the same motor through a slipping clutch, and is automatically set right every half minute by a signal transmitted from a master-clock. (The instrument as supplied to power-stations usually embodies its own master-clock, but the example shown here is actually controlled by the "Synchronome" master-clock (Catalogue No. 388) which is mounted on the west wall of this gallery.) The seconds-hand accordingly indicates standard time, and the amount by which frequency time differs from this can be read off at once from the position of the seconds-hand relative to the rotating dial.

Subsidiary dials are provided with minute- and hour-hands indicating standard time on the one and frequency time upon the other. Inv. 1932–618.

421. SYNCHRONOUS ELECTRIC CLOCK. Made and presented by Smith's English Clocks, Ltd.

This electrical clock consists essentially of a synchronous alternating-current motor which drives the hands through reduction gearing. If the frequency of the alternating current is kept strictly constant the clock will therefore go at a uniform rate.

The clock exhibited is driven by a 12-pole synchronous motor, the rotor of which makes 250 revolutions per minute when connected to a supply of about 220 volts at a frequency of exactly 50 cycles. In place of a seconds-hand the clock has a disc which rotates once a minute.

The clock is not self-starting, so that any interruption of current will cause it to stop, and so a starting mechanism is necessary. This consists of an arm carrying a pawl. When a small button on the outside of the clock is pressed and then released, this pawl engages with a ratchet wheel on the arbor of the rotor, and the strength of the small spiral spring which rotates the arm is so adjusted by the makers that the rotor just reaches synchronous speed as the pawl leaves the ratchet wheel. Inv. 1931–659.

422. SKELETON MOVEMENT OF SYNCHRONOUS ELECTRIC CLOCK. Presented by Ferranti, Ltd.

This is the movement of a Ferranti synchronous clock, a portion of the front plate of which has been cut away in order to show the mechanism. As in all synchronous motor clocks the hands are driven directly, through suitable gearing, by a synchronous alternating-current motor connected to the mains supply, and if the frequency of this is "controlled" (as described under Catalogue No. 420) the clock will be kept within a few seconds of correct time.

The rotor is of soft iron and has 36 poles; when running at synchronous speed it moves through the space of one pole each half-cycle, and therefore makes $166\frac{2}{3}$ revolutions per minute when connected to a 50-cycle supply. The rotor runs in special self-aligning bearings which incorporate a small reservoir for lubricant. The rotor spindle is fitted with a flywheel so that a brief interruption or diminution of current for a fraction of a second—due, for instance, to the blowing of a fuse in a neighbouring circuit—will not stop the clock.

Any long interruption will cause a stoppage, and as the clock is not self-starting a hand-starting device is fitted. When the knob at the side of the case is pulled out in order to set the hands, and then subsequently released, it is pulled back by a spring, and a pawl which it carries engages with a ratchet wheel geared to the rotor. The rotor is thus set in

motion, and the strength of the restoring spring is so chosen that this motion is slightly faster than synchronous speed, so that as the rotor slows down it soon reaches this speed, at which it is then maintained. The flywheel is not directly attached to the rotor spindle, but is connected with it by means of a spiral spring, as it is found that the light rotor alone is more easily locked into synchronism than if it were rigidly connected with the relatively heavy flywheel. Inv. 1934–63.

423. SYNCHRONOUS MOTOR CLOCK WITH SPRING RESERVE. Lent by Venner Ltd.

This is a combination of a synchronous motor clock and a spring-driven escapement clock.

Normally the movement is driven by the synchronous motor, but if the mains supply should fail the escapement starts and continues to drive the movement until the mains supply is re-established. The balance wheel of the escapement clock is provided with an armature which holds it in a position at the end of its swing as long as an electro-magnet is energised, but releases it when the electro-magnet is de-energised.

Provision is made for "exercising" the escapement clock every day even if the mains supply is uninterrupted.

The electro-magnet attracting the balance wheel armature is fed through a rectifier, and every 12½ hours this rectifier is short-circuited for about ten minutes allowing the escapement clock to run for this period.

If this daily "exercise" were not provided the oil in the escapement clock would be liable to congeal during long periods of inactivity, so that the clock would not be ready to start when called upon to do so by a mains failure. Inv. 1953–265.

VIII. THE QUARTZ CRYSTAL CLOCK

THE ELASTIC VIBRATIONS of quartz crystals are accompanied by small electrical effects, and the resulting electrical oscillations can be maintained and magnified by valve amplifier circuits. The oscillations are even more regular than those of the best pendulum clocks, and by means of electrical gearing they can be counted and recorded on a dial in a way similar to that which a mechanical clock counts and records the number of swings of a pendulum.

424. THE QUARTZ CRYSTAL CLOCK. Exhibit lent by the G.P.O. (Engineering Dept.).

This exhibit shows the method now used by Greenwich Observatory for measuring time to an accuracy of one-thousandth of a second per day; it includes three complete quartz crystal clocks, together with devices for inter-comparing the rates of the clocks and a dial showing the time indicated by one of them.

An auxiliary exhibit near by shows the way in which the crystals are selected, prepared and mounted, while two cathode-ray tubes in a neighbouring case illustrate the electrical gearing of the clocks and the method of comparing the rate of one clock with another.

[See The Horological Journal, Vol. 88, p. 184 (May, 1946); also the Journal of the Institution of Electrical Engineers, Vol. 93, part 3, No. 24, p. 233 (July, 1946).]

Inv. 1947–310 and 311, Photos 48/48, 49/48.

425. DIAGRAM SHOWING HOW THE QUARTZ CLOCK IS CHECKED BY OBSERVATIONS ON THE STARS. Lent by the G.P.O. (Engineering Dept.).

Inv. 1947–313.

426. DIAGRAM SHOWING HOW THE QUARTZ CLOCK IS SET RIGHT. Lent by the G.P.O. (Engineering Dept.). Inv. 1947–312.

427. DIAGRAM SHOWING HOW THE QUARTZ CLOCK CONTROLS THE EMISSION OF RADIO TIME SIGNALS. Lent by the G.P.O. (Engineering Dept.).

Inv. 1947–314.

428. TRANSIT TELESCOPE, TAPE CHRONOGRAPH, AND COUNTING ROOM.

Three mounted photographs showing the Royal Observatory's transit telescope, tape chronograph, and counting room. Presented by the Royal Greenwich Observatory.

Inv. 1952–186.

429. QUARTZ OSCILLATORS AND THEIR OVENS.

Four mounted photographs showing quartz oscillators and their ovens. Presented by the Royal Greenwich Observatory. Inv. 1952–187.

430. PHONIC MOTOR, SIGNAL FORMING UNIT, AND SEND RELAY UNITS.

Three photographs showing phonic motor, signal forming unit, and send relay units. Presented by the Royal Greenwich Observatory. Inv. 1952–188.

431. RECEIVING SET, PHONIC MOTOR, AND DECIMAL COUNTER.

Three photographs showing receiving set, phonic motor, and decimal counter. Presented by the Royal Greenwich Observatory. Inv. 1952–189.

432. CONTROL ROOM AT THE ROYAL OBSERVATORY.

Mounted photograph showing the control room at the Royal Observatory. Presented by the Royal Greenwich Observatory. Inv. 1952–190.

433. TAPE CHRONOGRAPH, BEAT COUNTERS, CALCULATING MACHINE, AND BEAT COUNTER RECORDS.

Four mounted photographs showing tape chronograph, beat counters, calculating machine, and beat counter records. Presented by the Royal Greenwich Observatory.

Inv. 1952–191.

434. COLD-CATHODE TUBE FREQUENCY DIVIDER. Constructed by the National College of Horology.

This unit further divides the 50 c/s. output from the Multivibrator frequency divider, giving a final output of one pulse per second. The division is achieved by a process of counting which takes place in three stages.

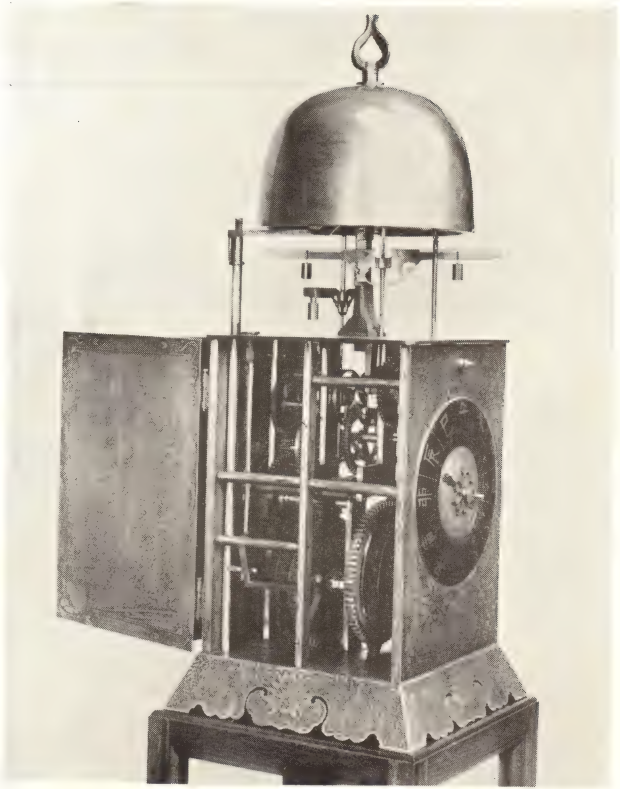
The 50 c/s. square waveform is fed to a driver tube which provides 50 sharp pulses per second which are fed to a pair of tubes. These are so connected that a pulse applied to both tubes causes the tube already conducting to be extinguished and the other tube to become conducting. Each tube therefore conducts every 1/25th second and the output from one is fed through another driver to a ring of five tubes.

In a similar manner to the first pair, the discharge transfers from one tube to the next at each pulse and therefore the pulse output from any one tube in the ring has a frequency of 5 c/s. A further ring of five tubes gives a final output pulse at a frequency of 1 c/s. which can be used in conjunction with other electronic equipment for various purposes, for example, to give time signals.

A relay, connected in the cathode circuit of one tube in the final ring of five, completes a low-voltage circuit once every second to drive a seconds impulse dial. Inv. 1954–457.

435. CENTRE-SECONDS IMPULSE DIAL. Presented by Gent & Co., Ltd.

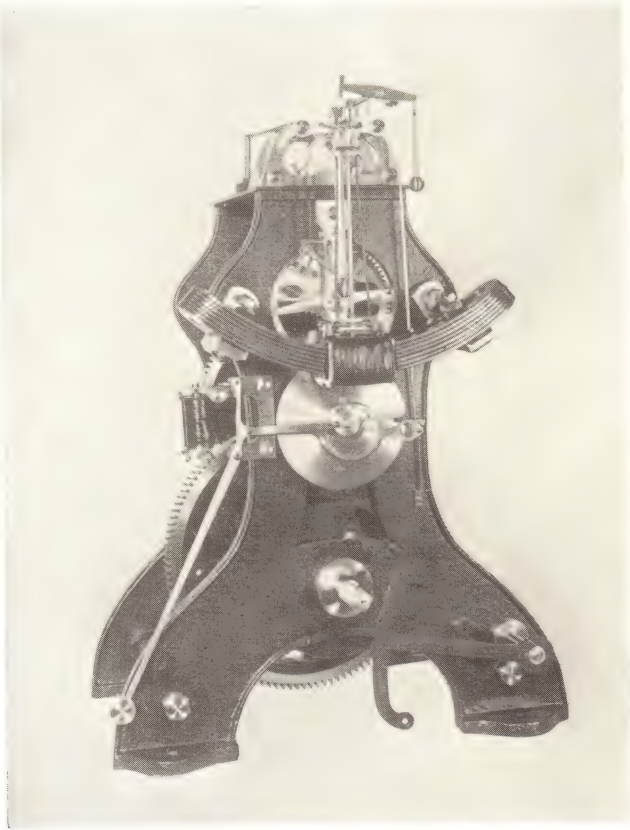
This is operated by the frequency divider controlled by the quartz crystal clock, and moves forward one second for every 100,000 vibrations of the crystal. Inv. 1954–175.



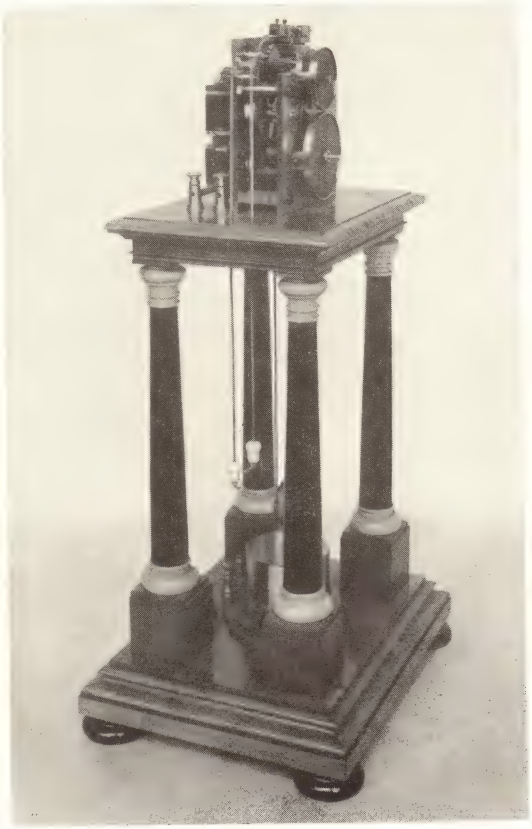
Japanese Lantern Clock (Cat. No. 358).

Japanese Bracket Clock, Spring-driven, with "bob" Pendulum. The "hour" marks are adjustable (Cat. No. 361).

PLATE IX



Wheatstone Master-clock of about 1870 (Cat. No. 372).



Hipp Chronoscope (Cat. No. 439).

PLATE X

IX. STOP-WATCHES AND CHRONOGRAPHS

THESE ARE INSTRUMENTS used for measuring short intervals of time, such as the duration of a race, or for recording the exact instant at which some event—such as the transit of the sun or of a star across the meridian—takes place.

Stop-watches or pocket chronographs are watches modified to allow all or part of the wheel-train to be stopped and started at will.

Chronoscopes are devices in which a train of wheels is kept in continuous motion, while an indicating hand can be thrown into or out of gear with it by means of an electro-magnetic clutch.

Recording chronographs are instruments in which a strip or sheet of paper is drawn uniformly beneath a pair of recording pens, one of which is deflected by means of an electro-magnet at the instant to be determined or at the beginning or end of the interval to be measured, while the other pen is operated at regular intervals by means of signals transmitted from a clock and so marks a time-scale upon the record.

Some of the Museum's stop-watches are shown with the main collection of watches (see Catalogue Nos. 259 to 264) but a small group (Catalogue Nos. 436 and 437) is included here with the chronoscopes and chronographs.

436. A COLLECTION OF STOP-WATCHES AND CHRONOGRAPH WATCHES. Presented by H. W. Ravenshaw, Esq.

1. An English stop-watch movement with verge escapement made by J. Stirling, London, about 1780. The movement can be stopped at will by sliding a small piece which presses a light arm against a wheel on the seconds-hand arbor.

2. An English stop-watch movement with verge escapement made by Charles Wilson, London, hall-mark 1784. Carries a centre seconds-hand and a small circle for minutes and hours. Stopping mechanism similar to that of 1.

3. An English movement with cylinder escapement made by Barraud, London, about 1800. Main circle reads minutes and hours, one circle 60 seconds and one circle 4 seconds divided into fifths of a second. Stopped by a light arm which presses on the escape wheel.

4. A modern Swiss movement with lever escapement. A complicated movement combining fly-back chronograph, quarter repeating mechanism and calendar showing day of the week, day of the month, month and phases of the moon.

5. An English chronograph movement made by Arnold & Dent, London, about 1840. There are two circles showing minutes and hours, one of which can be started and stopped independently of the other.

6. A Swiss independent centre-seconds chronograph movement, made probably about 1870. The centre seconds-hand beats whole seconds, there is a circle indicating minutes and hours on the chronograph mechanism, and another circle showing the time. The chronograph hands have to be set for each reading.

7. A modern Swiss "split-seconds" chronograph movement. Two centre seconds-hands travel together, and fly back as required, but one of them can be stopped and then when released flies either backwards or forwards to meet and travel with the main seconds-hand.

Inv. 1930–152 to 158.

437. CENTRE-SECONDS CYLINDER STOP-WATCH, by Ellicott. No. 8415. Lent by G. J. Fenn-Wiggin, Esq. Inv. 1952–59.

438. STOP-WATCH. Made by Messrs. E. Dent & Co.

This model shows a mechanism employed in watches of the type specially designed to measure the time taken by an event under observation. Such watches are generally, but not accurately, known as "chronographs."

The arrangements are such that, by pushing a button at the top three times successively, the recording hand is started, stopped, and made to return to its zero position, without affecting the ordinary timekeeping part of the watch.

The operating button is connected with a pawl which engages with a ratchet wheel of 18 teeth carrying six projections or castle teeth, and the latter engage with various pieces which effect the operations.

The first push brings a wheel carrying the hand into gear with the ordinary going train, the second throws it out of gear and brakes the wheel, and the third push removes the brake and returns the wheel to its zero position by means of a heart-shaped cam.

The apparatus is designed to allow an enlarged image to be thrown on a screen.

Inv. 1883–69.

439. CHRONOSCOPE (see Plate X). Made by M. Hipp, Neuchatel.

By this instrument intervals of time may be measured down to 0·001 second. It is suitable for use in experiments on the velocity of falling bodies, projectiles, etc.

It consists of a piece of clockwork actuated by a falling weight, two pointers in connection with the clock-train moving over two dials graduated to tenths and thousandths of a second respectively, and two electro-magnets, placed at the back of the stand, between which moves an iron armature. When a current passes through the upper electro-magnet the upward movement of the armature thereby occasioned throws the two pointers out of gear. The clockwork can be set in motion or stopped by means of two hanging cords.

A galvanometer serves to note the strength of the current passing to the electro-magnet.

Inv. 1889–38, Photo 8228.

440. TAPE CHRONOGRAPH.

In this instrument the tape on which the record is made is unwound from a spool and drawn past the recording pens by means of a pair of rollers. The rollers are driven from an induction-type electric motor whose speed is controlled by a centrifugal governor of the type commonly employed in gramophones. The drive takes place through a gear-box, which enables the speed of the moving paper to be maintained at $\frac{1}{2}$ in. or $1\frac{1}{2}$ ins. per second as desired.

Each recording pen consists of a fine metal tube, one end of which rests on the paper, while the other end dips into a small vessel containing ink. The ink is drawn up through the pen by capillary action and issues from the end resting on the paper. Each pen is mounted upon the armature of a small electro-magnet, and is deflected whenever a current (of about $\frac{1}{2}$ ampere) is passed through the electro-magnet.

Normally each pen traces a straight line upon the moving paper, but whenever the pen is deflected a break is made in the record and the position of this break can be measured afterwards with considerable accuracy.

When the chronograph is used in surveying work, one pen is deflected every second by means of a current transmitted through a contact on a chronometer, while the electro-magnet of the second pen is connected through a battery to a tapping key, which is operated by hand by an observer when a selected star is observed to cross the meridian.

In timing a race the tapping key may be operated by an observer at the start and again at the finish of the race. The record when completed is removed from the chronograph and the position of the break or breaks recorded by the observer is compared with the neighbouring scale of seconds recorded from the chronometer. In this way the exact instant of transit of the star or the duration of the race can be found with an error of a small fraction of a second.

Inv. 1933–169.

X. ALARM, STRIKING AND REPEATING MECHANISMS

ALARM AND STRIKING mechanisms are devices which are released by a timekeeper at a pre-set hour. An alarm rings a bell or sounds some other warning, while a striking mechanism causes the appropriate number of strokes to be sounded upon a bell or gong each hour.

Repeating mechanisms give, upon demand, an audible indication of the time, to the nearest hour, quarter or minute. They are usually incorporated in the movement of a clock or watch, but have also been made in detached form, for coupling to a non-repeating clock or watch.

This section of the Collection illustrates the mechanisms involved; actual watches fitted with them are embodied in the main watch collection. (See Catalogue Nos. 197 to 204 and 307 to 326.)

441. ALARM ATTACHMENT FOR KEY-WOUND WATCHES. Lent by Bruno Roberts, Esq., and Mrs. J. Williamson.

This apparatus, which is of French manufacture, was intended for use with the old type of key-wound watch, and enabled such a watch to sound an alarm at a specified time. The device consists essentially of a table for supporting the watch, a spring-driven alarm bell and a releasing mechanism, and its operation depends upon the fact that, as the watch goes, the squared winding arbor rotates.

A key which fits upon the winding arbor of the watch rotates clockwise with this arbor and carries an arm which moves a ratchet wheel through the space of one tooth for every rotation of the key. At the completion of a revolution of this wheel an arm rotating with it pushes aside a small pivoted lever which releases the L-shaped arm and permits the alarm bell to ring.

The time at which the alarm rings depends on the initial setting of the key and of the ratchet wheel, and so can be varied in steps. Inv. 1920–564.

442. STRIKING CLOCK MOVEMENT.

This is an English clock movement, made about 1880, with a locking-plate or count-wheel striking mechanism similar in principle to the striking arrangements of the earliest known clocks of the 14th century.

In this example the locking plate consists of a circular flange with a number of gaps, the striking distance between the successive gaps being proportional to 2, 3, 4, 5, etc., up to 12. The striking train of wheels is locked when the bent end of a lever falls between one of the gaps. In detail the series of operations involved in striking is somewhat complicated, but it is the distance between successive gaps which determines the number of blows struck. As the locking plate moves with the striking train, its position is independent of that of the hands, and when the latter are moved it is necessary to wait for the striking at each hour. Inv. 1883–53.

443. STRIKING CLOCK MOVEMENT.

This is an English clock movement, made about 1880, with the rack-striking mechanism, which was invented by the Rev. E. Barlow in 1676 and applied to clocks with the assistance of Thomas Tompion.

This mechanism is the form now generally used for domestic striking clocks, and it has the advantage, in comparison with the older locking plate striking mechanism, that the hands may be moved without waiting at each hour for the full number of strokes to be struck.

The position of a stepped spiral plate or "snail," which moves with the hour hand, determines the number of strokes on each occasion. Inv. 1883–95.

444. DETACHED REPEATING MECHANISM FOR USE WITH A BRACKET CLOCK. Presented by W. E. Miller, Esq., F.S.A.

This 18th-century apparatus is intended for use as an accessory to a bracket clock, enabling it to repeat the hour and nearest quarter whenever required. For this purpose the pinion on the projecting spindle of the apparatus is made to mesh with one of the motion wheels of the clock, so that the pinion is rotated once per hour by the clock.

On the same spindle as the pinion is a stepped cam which controls the number of

quarters to be struck; this cam carries a pin which engages with the star-wheel every hour and moves it through the space of one tooth. On the same spindle as the star-wheel is a "snail" which controls the number of hours to be struck.

When the cord at the back of the mechanism is pulled, the pinion engaging with the rack is rotated and the rack is pulled down until a pin mounted upon it meets the snail. The act of pulling the cord also winds up a spring contained in a flat barrel, and when the winding cord is released this spring drives the train of wheels in the reverse direction. The first of these wheels carries a number of pins which engage with the tail of the hour hammer; the number of blows which this hammer makes depends upon the number of pins which engage with the hammer as the spring runs down, and this number in turn depends upon the position of the snail.

The first wheel also carries a further set of three pins of differing lengths which engage with the tail of the quarter hammer after the hour has been sounded; the number of quarters struck depends upon the position of the stepped cam mounted on the long projecting spindle which, as described above, is controlled by the position of the minute-hand of the clock to which the mechanism is coupled.

If the positions of the snail and cam are correctly set in the first place of the mechanism will therefore repeat the hour and nearest quarter whenever the cord is subsequently pulled. Inv. 1937–290.

445. DETACHED REPEATING MECHANISM FOR USE WITH A KEY-WOUND WATCH. Presented by H. G. Easterbrook, Esq.

This mechanism, patented by Trusted in 1796 and made by Court of Henley, is designed to be controlled by a key-wound fusee watch, and when so used sounds the hour and nearest quarter whenever required. Its action depends upon the fact that with this type of watch the winding square rotates as the watch goes.

From the table upon which the watch rests a slotted spindle projects which fits over the winding square of the watch and is driven by it. As the spindle rotates, a pinion coaxial with it drives a straight rack which can slide in a horizontal direction and controls both the hour and the quarter striking.

To operate the mechanism the rack is first adjusted so that the pointer indicates the same time as that shown by the watch, and the milled disc on the projecting axis is then turned in an anti-clockwise direction as far as possible and released. During the turning operation a spring is wound up which, when released, drives a train of wheels, one of which carries a set of pins which operates the hour hammer.

Mounted upon the same axis as the milled disc is a drum carrying a number of projections; the disc can be turned until one of these projections meets a stop carried by the sliding rack; the angle through which the disc can be turned and hence the number of hours struck is thus determined by the position of the rack.

The numbers of quarters struck is determined by the angle through which a second spindle is turned as the spring is wound; this spindle bears an arm carrying three pins which operate the quarter hammer, and the angle through which it can turn is determined by the engagement of one tooth of a comb which it carries with one of three projections from a block carried by the sliding rack.

The position of the rack therefore controls both the hour and the quarter striking.

[See British Patent Specification No. 2,148 of 1796.] Inv. 1938–31.

XI. GAS CONTROLLERS AND TIME SWITCHES

FROM THE HOROLOGICAL point of view these may be compared with alarm and striking mechanisms, but instead of giving an audible signal at a pre-set hour they perform a definite control operation such as turning on or off a gas-cock or an electric switch.

Their main field of application is in switching street-lamps on at dusk and off at dawn, but they can also be used in a variety of industrial processes and in fact whenever an operation is required to take place at a specified time, or after a specified time interval.

The Science Museum's small collections of gas-controllers and time-switches for lighting purposes (Catalogue Nos. 446 to 455) are at present displayed with the Illumination Collection in the basement.

Two time-switches for general purposes (Catalogue Nos. 456 and 457) are exhibited in the Time Measurement Section.

GAS CONTROLLERS

446. RECONSTRUCTION OF THURGAR'S PIONEER GAS-CONTROLLER OF 1867. Lent by the Horstmann Gear Co., Ltd.

This is a modern reconstruction of a device patented by Dr. Thurgar of Norwich in 1867, and has been constructed according to the description given in the patent specification. The device is a clockwork controller running for eight days at each winding and is designed to turn the gas supply to the lamp on and off at pre-determined times. With the gas cock in the "off" position a special channel allows a small quantity of gas to pass, so that a small blue flame is left burning during the daytime. In order to screen this small flame from draughts, the controller automatically raises a small protecting globe as the gas is turned off and lowers the globe again as it is turned on.

The spring-driven clock movement is contained in the base of the instrument, and the spindle of this which would normally carry the minute-hand carries instead a small pawl which engages with a 24-toothed ratchet wheel, turning it through one tooth every hour in an anti-clockwise direction, the actual turning process occupying about 10 minutes each hour. Fixed to the ratchet wheel is a spindle which projects upwards from the clock case and carries a brass disc, fitted with two arms, one fixed to it and the other adjustable in a number of positions. As the disc rotates these arms engage in turn with a wire cam in the form of a figure 8, turning the cam through one-quarter of a revolution at each engagement. Engagement of an arm with the interior of the cam turns the gas off and at the same time causes the upper edge of the cam to raise the protective globe surrounding the flame, while engagement of an arm with the exterior of the cam turns the gas on and allows the globe to fall away from the flame. In falling, the globe pushes the cam round, turning on the gas supply relatively rapidly.

Examples of Thurgar's controller were installed at the Mint and at Somerset House, but they have now disappeared and no original example is known to exist.

[See British Patent Specification No. 2,435 of 1867.] Inv. 1938–133.

447. EXAMPLE OF GUNNING'S FIRST GAS-CONTROLLER FOR STREET-LAMPS. Presented by the British, Foreign and Colonial Automatic Light Controlling Co.

This clockwork device, patented by Gunning in 1897, was designed to be wound up by the lamplighter at dusk in the act of turning on the gas, and itself turned off the gas automatically a given number of hours afterwards, so that a second daily visit from the lamplighter during the night or early morning was rendered unnecessary.

Each evening at dusk the lamplighter pulls down the chain; this action rotates the large pulley-wheel in an anti-clockwise direction, thus winding up the driving spring of the clock mechanism, which then commences to drive the wheel slowly in a clockwise direction. On the same axis as the winding wheel is a brass disc with a projection on its outer edge; at the end of the winding operation this projection engages with a milled knob and pushes it downwards, turning on the gas supply to the lamp, which is then ignited by the lamplighter with his torch in the usual way.

A brass arm rotates on the same axis as the brass disc and can be held in a fixed position relative to the disc by means of a pin passing through the arm and also through any one of a series of holes in the disc. The holes are numbered from 1 to 18, and with the pin in

hole number 10, say, the arm will engage with the milled knob, push it upwards and so turn off the gas just 10 hours after it was turned on by the lamplighter.

This device was soon superseded by the fully automatic controller exhibited adjacently.

[See British Patent Specification No. 7,011 of 1897.] Inv. 1938–462.

448. EXAMPLE OF GUNNING'S FIRST FULLY AUTOMATIC GAS-CONTROLLER. Presented by the British, Foreign and Colonial Automatic Light Controlling Co.

This was patented by Gunning in 1899 and was the first commercially successful fully automatic controller, turning the gas on as well as off. A small by-pass with continuously burning flame was provided in order to light the main burner when its supply was automatically turned on by the controller.

The clockwork movement runs for eight days at a winding, and its function is to rotate a brass disc anti-clockwise once every 24 hours. Coaxial with the disc are two brass arms, each of which can be fixed relative to the disc by means of a screw passing through the arm and also through any one of a series of holes in the disc. The two arms engage alternately with an eight-pointed star-wheel mounted on the end of the plug of the gas-cock, turning it through one-eighth of a revolution at each engagement. The plug is provided with two passages at right angles, so that at every alternate position gas is permitted to pass through it. The engagements of the arms with the star-wheel therefore turn the gas supply to the lamp alternately on and off. The times at which these operations take place are determined by the positions of the arms relative to the brass disc, and can be varied in steps of one hour to suit the season of the year by suitably adjusting the positions of the arms.

The controller requires weekly winding and adjustment of the arms at somewhat rarer intervals.

[See British Patent Specification No. 25,567 of 1899.] Inv. 1938–463.

449. MODERN "GUNFIRE" GAS-CONTROLLERS. Presented by The British, Foreign and Colonial Automatic Light Controlling Co.

The controller shown on the left, giving slow lighting and extinguishing, is the modern counterpart of Gunning's first fully-automatic controller exhibited adjacently. The arms which engage with the eight-pointed star-wheel are now continuously adjustable in position and the dial is graduated in hours and quarters.

The controller shown on the right is designed to give slow extinguishing and quick lighting.

Each of its two operating arms carries a pin projecting backwards, the "off" pin being shorter than the "on" one. As the dial rotates anti-clockwise the "off" pin engages with one end of a lever which is coaxial with the plug of the gas-cock. The pin slowly pushes this lever round, turning the gas "off." Near the end of its travel a pallet projecting backwards from the lever engages with a catch mounted upon a trigger arm and is locked in the "off" position.

The long pin carried by the "on" arm of the controller engages with the trigger arm and unlocks the catch, releasing the gas-cock lever, which is rapidly rotated by the helical spring attached to its tail, thus turning the gas "on."

The dial of the example exhibited has been partly cut away in order to reveal the lever and trigger. Inv. 1938–465 and 466.

450. EARLY HORSTMANN GAS-CONTROLLER FITTED WITH A "SOLAR" DIAL. Presented by The Horstmann Gear Co., Ltd.

This is an example of the first type of Horstmann gas-controller for street-lamps, and is believed to be the first controller fitted with a "solar" dial, a device, patented in 1904, which automatically adjusts the position of the controlling arms according to the season of the year, so that the street-lamps will be lighted at dusk and extinguished at dawn throughout the year.

The solar dial mounted at the back of the controller is rotated at the rate of one revolution in 24 hours by the clock movement and as it rotates each of its two controlling arms in turn engages with a pivoted arm, releasing a train of clockwork which rotates a brass disc on the front of the controller through half a revolution. A pin mounted on this disc engages with one or other of two projections from a sliding piece and pushes the piece to the left or to the right as the disc makes its half-turn. The sliding piece is connected by means of a slotted crank with the plug of the gas-cock, so that at successive half-turns of the brass wheel the gas supply to the lamp is turned alternately on and off.

The arrangement has the advantage that the sliding piece can be moved by hand to turn the gas on or off if required without disturbing the subsequent series of automatic operations.

This was probably the first controller giving quick action—a desirable feature preventing the risk of "lighting back" when used with incandescent burners.

[See British Patent Specifications Nos. 27,849 of 1904 and 27,290 of 1905.] Inv. 1938–134.

451. EXAMPLE OF THE "LONDON" GAS-CONTROLLER. Presented by The Gas Meter Co.

This is a later example of a type of controller first introduced in 1913 for lighting and extinguishing gas-burners at pre-determined times, with arrangements for cutting off the by-pass supply when the burners are alight. The clockwork movement is controlled by a lever escapement and the timekeeping and operating trains of wheels are driven from opposite ends of the same mainspring.

The dial rotates in a clockwise direction once every 24 hours, and a series of notches is cut in its rim into which the operating arms can be sprung. Each operating arm is fitted with a pin projecting backwards which releases the operating train by means of an arrangement similar to a striking mechanism, the locking-plate of which has four evenly spaced notches. The plug of the gas-cock is coaxial with this locking-plate, and both make one-quarter of a turn together at each operation, turning the gas alternately on and off.

The valve or cock is designed so that it may be cleaned by removing the cap at the back of the casting.

The case of the example exhibited has been fitted with transparent windows and the dial has been partly cut away to reveal the locking-plate.

[See British Patent Specifications Nos. 23,789 of 1911, 23,993 of 1912 and 3,964 of 1915.]
Inv. 1938–675.

452. EXAMPLE OF THE "KINGSLAND" GAS-CONTROLLER. Presented by the Gas Meter Co.

This type of controller was first marketed in 1928. The dial is similar to that of the adjacent "London" controller and is rotated in an anti-clockwise direction once every 24 hours by the spring-driven clockwork mechanism.

The plug of the gas-cock has a rocking motion and when it is turned as far as it will go in a clockwise direction the gas supply to the burners is full on and the by-pass supply is cut off. The process of extinguishing is a slow one. A pin mounted on the "off" control arm engages with a projection on a rocking lever and pushes the lever slowly round; this movement causes a pin on the other (right-hand) end of the rocking lever to engage with a slotted disc which is coaxial with the plug of the gas-cock and to push this disc round anti-clockwise, carrying the plug round with it. The first part of the movement opens the by-pass supply and allows the by-pass to light; the remainder of the motion slowly extinguishes the main burners. At the end of the motion the rocking lever is locked in position, being caught up on one prong of an auxiliary forked lever.

At lighting, a pin mounted on the "on" control arm engages with the left-hand prong of the forked lever and suddenly releases the rocking lever, which is rapidly rotated by its helical spring, turning on the supply to the burners. The rocking lever is, however, prevented for a few minutes from completing its travel by a pin within the fork of the forked lever, but is finally released, completing its motion and so turning off the supply to the by-pass.

The case of the controller exhibited has been fitted with transparent windows and the dial, which is partly cut away, is disconnected from the clock and operable by means of a pulley and belt drive, so that the sequence of operations can be studied by the visitor.

[See British Patent Specification No. 318,320.] Inv. 1938–676.

TIME SWITCHES

453. EARLY AND MODERN ELECTRICAL TIME-SWITCHES. Presented by the Horstmann Gear Co., Ltd.

The mechanism of the early time-switch on the left is identical with that of the first Horstmann gas-controller, patented in 1904–5 and described in an adjacent label, but in the time-switch the operating crank is connected to an electric tumbler switch instead of to the plug of the gas-cock. The switch is of a type first introduced about 1905.

The modern time-switch on the right is driven by a synchronous electric motor and is suitable for use in localities where the alternating-current electric supply is time-controlled. The switch is fitted with the Horstmann solar dial giving continuous automatic adjustment of the switching times to suit the season of the year. The contacting gear is robust and gives a quick break of contact. The time indicator has two points marked "W" and "S" for use during winter and summer times respectively.

[See British Patent Specifications Nos. 27,849 of 1904, 27,290 of 1905 and 395,813.]
Inv. 1938–137 and 138.

454. "SOLAR" DIAL USED IN AUTOMATIC SWITCHING OF STREET-LAMPS. Made and presented by Venner Time Switches Ltd.

Clocks with dials of this type are used for automatically switching on electric street-lamps at sunset and switching them off at sunrise. The dial as a whole is rotated by the

clock once every 24 hours, and the actual switching is carried out with the aid of two arms mounted on the dial whose positions relative to the dial are automatically varied according to the season of the year, so as to allow for the variation in the times of sunset and of sunrise. The dial exhibited shows the way in which this adjustment is made.

The small star-wheel at the side of the dial is turned through one tooth each day by engaging with a fixed pin; this mechanism can be seen on the adjoining exhibit. On the same axis as this star-wheel is a worm which drives a worm wheel and rotates the latter once in a year. Coaxial with the worm wheel are the date indicator on the face of the dial and, behind the dial, a wheel carrying a pin which projects through a slot in a pivoted arm. As the pin revolves with the wheel, the arm is made to rock back and forth once in a year, and this motion is communicated to the "in" switching arm by means of a rack and pinion. A duplicate device, operated by a pin on the worm wheel, operates the "out" switching arm.

The dial exhibited is suitable for use in the latitude and longitude of London, but by suitable choice of the dimensions and of the initial setting of the moving parts, dials are made which are suitable for use in any part of the world other than the polar regions.

Inv. 1932–474.

455. STREET LIGHTING SWITCH OPERATED BY SYNCHRONOUS MOTOR CLOCK WITH "SOLAR" DIAL. Lent by Venner Ltd.

This exhibit shows the way in which a modern time-switch with solar dial controls the switching of street lamps.

In the normal instrument the solar dial is rotated by a synchronous motor once every 24 hours, but in the clock exhibited here some gearing has been omitted so that the dial rotates once per minute.

The switching is carried out by means of pins mounted on the three arms of the dial; the position of two of these relative to the dial is automatically varied according to the season of the year, so as to follow the changing times of sunset and sunrise, while the third pin is fixed to operate at a selected time adjustable between 11 p.m. and 1 a.m. The switch controls two separate electrical circuits: both are switched "on" at sunset, and one is switched "off" at the chosen time between 11 p.m. and 1 a.m.; the other goes "off" at sunrise. Details of the switching action can be seen by watching the switch at work; it will be noticed that both "make" and "break" are rapid.

The model street-lamp is controlled by the circuit switching "off" at midnight.

Inv. 1953–336.

456. MODERN PROGRAMME CLOCK. Presented by Industriaktiebolaget Reflex, Sweden.

The notable feature of this programme clock, which provides pre-set automatic switching for a whole week, is the ingenious way in which the switching programme is set.

A spring-driven clock movement drives a fourteen-grooved drum which makes one revolution every 12 hours. The particular groove or 12-hour period in operation is shown in an aperture at the side by the day name; 0 to 12 hours (midnight to midday) by black letters on a white ground and 12 to 24 hours (midday to midnight) vice versa. The drum can be rotated manually by the glass disc on the face of the clock.

A small container housing 50 steel balls is mounted at the side of the drum and is moved transversely the width of one groove every 12 hours, by a pin on the drum engaging with oblique slots on the container. Incorporated in the container is a mechanism, operated by the lower front knob, for pressing the steel balls into the grooves, which are 0·03 mm. narrower than the diameter of a ball.

The week's switching programme is set up by rotating the drum via the glass disc until "Sun," 0–12 hours is indicated. The line on the glass disc is then set opposite the desired switching time, and turning the front knob will set a ball on the drum for the first switching operation. Subsequent switching times for each day are set in a similar manner. Finally the line on the glass disc is set coincident with the hour hand.

The balls on the drum now form a series of projections and, as the drum revolves, operate a micro-switch mounted on the ball container.

Removal of the balls after they have carried out their switching is achieved by causing a plastic comb to rest in the drum grooves; when the drum is then turned anti-clockwise the balls are forced from the grooves and fed back into the container. Inv. 1952–296.

457. ELECTRICALLY WOUND TRIPLE-POLE CHANGEOVER TIME-SWITCH. Lent by Venner Ltd.

This modern time-switch is fitted with a dial to give three "on" and three "off" switchings daily, and a selective device to enable one or more of these switchings to be omitted on a chosen day or days.

The example shown is operated by a mechanical clock electrically wound from the A.C. mains supply, but other models are available which are respectively hand-wound, synchronous motor-driven, and driven by a synchronous motor with 30-hour spring reserve which comes into operation if the mains supply fails. Inv. 1953–337.

XII. TIME RECORDERS

THESE ARE instruments which make a printed record of the time of day at which a certain event takes place. They are most widely used for registering the time of arrival and departure of employees, but they can also be utilised for a variety of other purposes, such as to record the times at which omnibuses pass a definite point, to check the rounds of a night-watchman, or to register the times at which a safe, strong-room or shop is locked or unlocked or at which jobs are started and finished.

Photographs of pioneer time recorders are exhibited, together with an example of a modern instrument.

458. "BUNDY" TIME RECORDER. From photographs lent by I.B.M. United Kingdom, Ltd.

These show the earliest form of workmen's time recorder, invented by W. L. Bundy in the U.S.A. in 1885. It consists of a mechanical clock which rotates a set of type wheels and is operated by any one of a series of numbered keys, one of these being issued to each employee. The process of turning the key in the key-hole in the front of the machine brings the engraved number on the key in line with the time as indicated by the hour wheel, and the record is then stamped on a continuous roll of paper. The employee's number thus appears against the time he has recorded, while the records of different employees appear in the order of their arrival and departure.

In the earliest Bundy recorders the time was shown only to the nearest hour, but in later models minutes as well were recorded.

The Bundy recorder is now almost obsolete, but many examples are still in use, particularly as traffic recorders on tramway and omnibus routes.

Inv. 1934–664, Photos 7745, 7446.

459. DIAL TIME RECORDER. From a photograph lent by I.B.M. United Kingdom, Ltd.

The photograph shows the earliest dial type recorder invented in 1888 by Alexander Dey of Aberdeen. In this type of machine the records made by different employees appear in their numerical order, instead of in chronological order as in the earlier "Bundy"

Inv. 1934–665, Photo 7447.

460. "SUPERVISED" ELECTRIC CARD TIME RECORDER. Lent by I.B.M. United Kingdom, Ltd.

This machine prints automatically on separate cards a tabulated record of the times of arrival and departure of employees. When a time card is placed in the slot in the front of the recorder it automatically prints on the card in the correct position the day, hour and minute of the operation. A completed card is exhibited adjacently. The cards are usually kept in numbered racks at the side of the machine.

The clock is operated electrically by impulses received from the International master-clock (Catalogue No. 411) mounted on the pillar near by. An impulse is received every minute and this advances the time-indicating numerals and also advances the minute type wheel in the mechanism, which advances the hour type wheel at the 60th minute, which in turn periodically advances the day type wheel.

When a card is inserted, the printing hammer presses the card against the ink-ribbon, which is immediately in front of the correct time portion of the type wheels, and the correct time is thus printed on the card. The red records on the card indicate lost time and overtime—the original device for automatically printing such times in a distinctive colour different from that employed for ordinary (regular) times was patented by the International Time Recording Co. in 1905. The times for the operation of the colours can be set to any schedule, and a similar mechanism sets the recorder for the correct position "in" or "out" and also for the correct line corresponding to the day on which the record is made.

The recorder exhibited is operated and controlled entirely from the master-clock through its relay cabinet: details of the method employed are given in the labels for the master-clock and its secondary dials.

Inv. 1951–181.

XIII. MISCELLANEOUS

461. OIL PAINTING OF JOHN HARRISON. Lent by W. H. Barton, Esq.
Oil painting of John Harrison (1693–1776), by T. King. Inv. 1884–217, Photo 1103/52.

462. DIAGRAM GIVING A GRAPHICAL HISTORY OF TIME MEASUREMENT SINCE 1300 A.D. Prepared in the Museum. Inv. 1931–781.

463. DIAGRAM SHOWING PROGRESS IN THE ACCURACY OF TIMEKEEPERS THROUGH THE CENTURIES. Inv. 1948–298, Photo 395/48.

XIV. LIST OF THE MORE IMPORTANT OBJECTS NOT ON EXHIBITION

As mentioned in the Introduction to this volume, most of these objects may be inspected on written application to the Director and Secretary, the Science Museum, South Kensington, London, S.W.7, provided that sufficient notice is given. Some are stored in the Museum itself, and fairly readily accessible, others are in outlying stores.

They include further sand-glasses from the Abbot Horne Collection and a collection of pocket sundials presented to the Museum in 1938 by W. E. Miller, Esq.: this latter will be referred to as "the Miller Collection".

SAND-GLASSES AND OTHER NON-MECHANICAL DEVICES

24-INCH HOUR-GLASS, in wooden mount. Inv. 1942–21.

CHINESE INCENSE CLOCK. Presented by F. H. Nash, Esq. Inv. 1952–184.

21½-INCH SAND-GLASS, in wooden mount. From the Abbot Horne Collection. Inv. 1953–448.

SUNDIALS

PLASTER CAST OF ANCIENT STONE SUNDIAL. Presented by the Archaeological Museum, Madrid. Inv. 1876–322.

HORIZONTAL SUNDIAL. Made by F. X. J. Bovius, 1712.

This early 18th-century German dial is made of hone stone and has a silver gnomon inclined for a latitude of 49°.

It is elaborately carved and bears several inscriptions. Inv. 1880–33.

SLATE DIAL-PLATE OF A HORIZONTAL SUNDIAL SHOWING ITALIAN HOURS. Presented by Dr. W. L. Hildburgh. Inv. 1946–171.

AZIMUTH SUNDIAL.

This early 18th-century dial indicates the time by means of the direction of the sun and is said to have been made by Rudolph Gleich, Vienna.

A pewter dial plate is mounted on a wooden base with spandrel ornaments, and is marked with a series of hour lines. A hinged arm turning on the centre of the plate carries at one end a vertical style and at the other a pointer which can be made to slide radially along the arm by means of a rack and pinion connected with a hand which moves over a scale of months.

In use the instrument is oriented, the hand set for the date, and the arm moved until the shadow of the style falls horizontally along the arm. The pointer will then show the time on the appropriate hour scale. Inv. 1894–107.

ORTHOCHRONOGRAPH. Made by Messrs. R. Webster & Son. Presented by T. H. Court, Esq.

This is a portable instrument for ascertaining correct time by observing equal altitudes of the sun before and after it crosses the meridian. The principle was suggested by Mr. Lowman and the apparatus was exhibited at the British Association Meeting in 1844. Inv. 1916–8.

BRASS PORTABLE SUNDIAL, inscribed T. Taborski W. Krakowie. Inv. 1894–8.

UNIVERSAL RING SUNDIAL. Made by Sadtler, Vienna. Presented by T. H. Court, Esq.

This 18th-century dial has a pin gnomon parallel to the earth's axis and indicates the time by the position of the pin's shadow on a graduated hour circle which is parallel to the equator. Inv. 1918–97.

COMPASS SUNDIAL, by Franz Knitl, Linz. Inv. 1880–35.

HORIZONTAL AND ANALEMMATIC SUNDIAL. Made by Baradelle, Paris.

This 18th-century instrument is a combined horizontal and analemmatic sundial with a folding gnomon having an angle of 45° and a vertical back edge which serves as the style for the analemmatic dial.

In order that the vertical edge may be adjusted for the time of the year, the whole horizontal dial is made to slide on the plate of the analemmatic dial. A small arc on the north side of the instrument enables the dials to be so inclined as to serve for any latitude between 42° and 55°. Inv. 1894–28.

HORIZONTAL AND RING SUNDIAL. Made by M. Kolwein, Vienna.

This late 17th-century instrument consists of an equatorial ring sundial mounted on the top of the gnomon of an ordinary horizontal sundial which is set for a latitude of 48° 14'. Inv. 1880–40.

UNIVERSAL SUNDIAL.

This 18th-century equatorial dial is arranged to show the time by means of pointers moving over hour and minute circles, and it is inscribed "Joseph Modestin in Chrudin" (Bohemia). Inv. 1880–45.

BRASS HELIOCHRONOMETER OF WHEATSTONE TYPE. Lent by King's College, London. Inv. 1949–301.

POCKET COMPASS SUNDIAL FROM KOREA, WITH ALTERNATE CHINESE AND ARABIC HOUR-NUMERALS. Presented by Dr. W. L. Hildburgh. Inv. 1953–237.

CHINESE IVORY TABLET SUNDIAL. From the Abbot Horne Collection. Inv. 1953–316.

UNIVERSAL POCKET SUNDIAL, by Grasl. Presented by Thomas H. Court, Esq. Inv. 1916–324.

BRASS UNIVERSAL COMPASS SUNDIAL, by Bithray, Royal Exchange, London. Presented by Mrs. A. H. Lloyd. Inv. 1947–280.

PERSIAN POCKET SUNDIAL. Inv. 1894–111.

POCKET ALTITUDE SUNDIAL, paper on wood, inscribed "Hutchinson deli . . . ." Inv. 1951–272.

FERGUSON HELIOCHRONOMETER. Inv. 1951–302.

FROM THE MILLER COLLECTION

IVORY TABLET SUNDIAL, signed "H.D." (probably Hans Ducher). Inv. 1938–374.

IVORY TABLET SUNDIAL, by Jasper Milner. Inv. 1938–371.

DISC SUNDIAL WITH VANE, inscribed Roma, A.D. 1592. Inv. 1938–348.

TABLET SUNDIAL, by Hans Troschel. Inv. 1938–361.

OCTAGONAL POCKET COMPASS SUNDIAL WITH CONCENTRIC LUNAR DIAL. Inv. 1938–367.

OVAL POCKET COMPASS SUNDIAL, by Le Sueur, Gisors. Inv. 1938–341.

OCTAGONAL BRASS POCKET COMPASS SUNDIAL, by Langlois a Paris. Inv. 1938–343.

PERSIAN POCKET COMPASS SUNDIAL. Inv. 1938–373.

UNIVERSAL COMPASS SUNDIAL, by And. Vogel. Inv. 1938–359.

BOXWOOD VERTICAL SUNDIAL BY HIERONYMUS VULPARIA, 1592. Inv. 1938–351.

RING DIAL $1\frac{1}{8}$ in. DIAMETER. Inv. 1938–363.

UNIVERSAL RING DIAL signed Manuel de Ballesteros. Inv. 1938–369.

NOCTURNALS

EARLY 17TH-CENTURY ITALIAN BRASS GILT NOCTURNAL. Inv. 1880–42.

WOODEN NOCTURNAL stamped "Mr. Edward Tyzack, 1713." Lent by E. Ball Knobell, Esq. Inv. 1908–165.

NOCTURNAL AND POCKET UNIVERSAL SUNDIAL, both showing Italian hours. Incomplete. Inv. 1952–324.

PERPETUAL CALENDARS

PERPETUAL ALMANACK, engraved "Storr fecit York." Presented by Thomas H. Court, Esq. Inv. 1938–753.

SILVER PERPETUAL CALENDAR dated 1765. Inv. 1943–21.

FRENCH IRON SQUARE SUNDIAL AND PERPETUAL CALENDAR, dated 1624. Inv. 1944–43.

DIPLEIDOSCOPES

DIPLEIDOSCOPE. Made by Messrs. E. Dent & Co. Bequeathed by W. Tucker Radford, M.B.

This is an instrument for determining the time of apparent solar noon by means of coincidence of two images of the sun. It was originally patented by J. M. Bloxam in 1843.

It consists of an outer piece of glass combined with two interior mirrors to form a hollow prism, the axis of which is fixed parallel to the earth's axis. When light from the sun falls on the instrument, some of it is reflected from the outer surface and gives an image of the sun, while the remainder passing through the outer glass falls on one of the inner mirrors and is reflected on to the other mirror and from there out of the prism to form a second image. If the angle between the outer glass and the direction of the light from the sun be equal to the angle between the two mirrors, these two images will coincide, and the instrument is so fixed that this occurs at solar noon. Inv. 1900–178.

PORTABLE DIPLEIDOSCOPE. Lent by E. Dent & Co. Inv. 1876–1021.

DIPLEIDOSCOPE WITH CLOCK GEARING. Presented by T. H. Court, Esq.

This is similar in principle to other dipleidoscopes, but the prism can be turned on its axis to allow for observations of the sun at other times than noon. Inv. 1917–98.

CLOCKS AND CLOCK MECHANISMS

TWO BELLS FROM WELLS CATHEDRAL.

These bells were formerly in use with the clocks at Wells, and probably date from the 14th century. Inv. 1887–73.

THREE CAST STEEL BELLS SET UP IN CONNECTION WITH THE WELLS CATHEDRAL CLOCK. Lent by Messrs. Vickers, Sons & Co., Sheffield.

These bells were made by Messrs. Vickers in the 19th century and are made of cast steel instead of the usual bell metal. Inv. 1884–76.

16TH-CENTURY AUGSBURG CLOCK (copy). Lent by C. L. Goggs, Esq.

This is an electrotype copy of a clock by Jeremias Metzker of Augsburg, dated 1564. It is remarkable for the variety of information given on its many dials.

The clock is fitted with a 19th-century French movement which operates only the main 24-hour dial on the front of the clock. Inv. 1949–207.

MUSICAL CLOCK. Bequeathed by R. G. Webb, Esq.

This clock, made by Samuel Cleghorn of London about 1880, is an example of the rather elaborate type of domestic clock which developed from the simpler bracket clock of the early 19th century. It is fitted with three separate trains of wheels for timekeeping, striking and tune-playing respectively, each of which is driven by a spring through a fusee.

The timekeeping or "going" train is controlled by a light pendulum through a verge escapement, and represents no advance on that of the earliest pendulum clocks of 1660–70.

The striking mechanism is of the rack type invented by Barlow in 1676.

Inv. 1931–63.

BAROMETRIC COMPENSATION FOR THE DENT STANDARD CLOCK. Lent by E. Dent & Co.

Photograph of the barometric compensation for the Dent standard clock of 1872 for the Royal Observatory, Greenwich. Inv. 1876–76.

WATCH MECHANISMS

CYLINDER ESCAPEMENT. Made by Messrs. E. Dent & Co.

This model was designed to allow an enlarged image to be projected, by reflection, upon a screen. It represents the cylinder or horizontal escapement, invented by George Graham about 1720, which was formerly extensively used for watches. Inv. 1883–65.

LEVER ESCAPEMENT. Made by Dent.

This model was designed for use in connection with a projecting lantern and it represents the lever escapement, which in a modified form is now almost universally employed for pocket watches. Inv. 1883–66.

KEYLESS MECHANISM. Made by Dent.

This model was designed for projection by reflection on to a screen and it represents a keyless mechanism, introduced about 1850, which has been extensively used in Swiss and other watches.

The essential feature of the mechanism is a pair of ratchet wheels, arranged with their teeth on the ends of cylinders, one of which drives the other. For motion in one direction the two sets of teeth interlock and move together, but for motion in the opposite direction the teeth of the driving wheel slide out of engagement. Provision is also made for setting the hands. Inv. 1883–68.

CHRONOMETERS

COMPENSATION BALANCE-WHEEL WITH MERCER'S AUXILIARY COMPENSATION. Presented by G. R. Kirby, Esq. Inv. 1936–55.

JAPANESE CLOCKS

JAPANESE "LANTERN" CLOCK.

This is one of the earlier types of Japanese clock, the movement being made entirely of iron, and probably dates from the late 17th century.

It is fitted with two separate escapements, one for use during the day and the other for the night when the Japanese "hours" were of a different length.

The clock strikes on the usual Japanese system, the sequence of strokes beginning at either noon or midnight being 9, 1, 8, 2, 7, 1, 6, 2, 5, 1, 4, 2.

The case of the clock is of iron inlaid with silver and brass and a translation of an inscription on one of the uprights reads—"Fuwa Gembei, an inhabitant of Nagoya, Bishu (Owari) made this." Inv. 1893–171.

SMALL JAPANESE CLOCK IN THE FORM OF AN "INRO." Bequeathed by R. L. Hine, Esq. Inv. 1951–568.

ELECTRIC CLOCKS

BAIN ELECTRIC CLOCK. Presented by G. Brown, Esq.

This electrically driven clock is similar in principle to the long-cased Bain electric clock (Catalogue No. 370), but in this modification the coils are fixed and the permanent magnets are mounted on the pendulum. Inv. 1928–208.

SCOTT'S ELECTRICALLY DRIVEN CLOCK. Lent by Herbert Scott, Esq.

This clock, which was patented by Mr. H. Scott in 1902, and made by the British Ever-Ready Electrical Co., Ltd., resembles the Hipp clock (Catalogue No. 380) in that an impulse from an electro-magnet is given to the pendulum whenever its arc of swing falls below a predetermined value. With a new battery the pendulum thus receives few but powerful impulses, while with a run-down battery the impulses are weaker but more frequent, the average arc thus being kept fairly constant and independent of the battery voltage.

The impulse is not given at the middle of the swing, and the force necessary to make contact is supplied by the pendulum.

[See British Patent Specifications No. 10,271 of 1902 and No. 2,879 of 1903.] Inv. 1912–240.

HOLDEN'S ELECTRICALLY DRIVEN CLOCK. Presented by F. Holden, Esq.

This clock, patented by F. Holden in 1909, is of the type in which the pendulum makes a contact and receives an impulse from an electro-magnet every swing. It is arranged that both contact and impulse shall occur sharply at the middle of the swing, so that variations in these have practically no direct influence on the timekeeping. The clock behaves as an electromotor running under light load and therefore small variations in this load have very little influence on the arc of swing, which is determined only by the battery voltage.

[See British Patent Specifications No. 14,873 of 1909 and No. 14,126 of 1910.] Inv. 1914–596.

ELECTRIC PENDULUM OF HOLDEN TYPE. Presented by W. R. T. Foreman, Esq. Inv. 1949–25.

SELF-WINDING MASTER-CLOCK AND IMPULSE DIAL. Presented by F. Hope-Jones, Esq.

This clock, patented by D. van de Plancke in 1885, and made by La Précision Cie, Brussels, is an ordinary mechanical pendulum clock which makes an electrical contact every half minute; an electro-magnet is then energised and attracts an armature, the motion of which winds up the driving spring of the clock. At the same time a current impulse is sent out to drive the subsidiary dials.

[See British Patent Specification No. 8,538 of 1885.] Inv. 1912–224 and 225.

PERRET MASTER-CLOCK. Made and lent by Vve. David Perret Fils, Neuchatel.

This type of clock, introduced by Perret about 1900, is a balance-wheel controlled mechanical clock which makes an electrical contact every minute: an electro-magnet then attracts an armature which resets the driving spring. The clock was used as a master-clock, sending out impulses every minute to drive subsidiary dials similar to one also in the collection. Inv. 1912–250.

PERRET IMPULSE DIAL. Lent by Messrs. Dykes Bros., Glasgow.

This dial is intended for use with a Perret master-clock. It was introduced by Perret about 1900 and is of the type in which a ratchet wheel is advanced through the space of one tooth for each impulse. Inv. 1912–400.

CAMPICHE IMPULSE DIAL MOVEMENT. Presented by F. Hope-Jones, Esq. Inv. 1912–232

CHRONOGRAPHS AND CHRONOSCOPES

BASHFORTH'S CHRONOGRAPH. Presented by the Rev. F. Bashforth.

This chronograph was invented by the donor about 1865, and was used for measuring the times occupied by projectiles in passing over a succession of equal spaces.

The instrument consists of a fly-wheel which can be rotated by hand about a vertical axis and carries a cylinder with a prepared paper surface. A platform, to which two electrically operated markers are attached, is mounted on a slide by the side of the cylinder and is caused to descend slowly by means of a cord wound around a drum which is geared with the axis of the fly-wheel. The markers trace spirals on the cylinder and are controlled by means of two electro-magnets, the upper of which is in circuit with a number of screens through which the projectiles pass. The passage of a projectile through each successive screen causes a corresponding interruption of the current and is recorded by a deflection of the marker upon the surface of the cylinder. The circuit of the lower electro-magnet is interrupted once a second by a clock beating half seconds and the lower marker consequently gives a time scale.

Each screen consists of a series of cotton threads suspended from the ends of brass spring wires and extended by means of weights at the bottom. The distance between adjacent threads is less than the diameter of a projectile, and the spring wires pass through holes in vertical copper plates. The circuit is closed by the contacts between the spring wires and the copper plates, but when a thread is cut by a projectile the circuit is broken for a short interval while the corresponding spring flies from the bottom to the top of its hole.

This instrument was used in experiments referred to in "Reports on experiments made with the Bashforth chronograph to determine the resistance of the air to the motion of projectiles, 1865–1870." Generally 10 screens were used at intervals of 150 feet.

Inv. 1876–377.

LE BOULENGÉ CHRONOGRAPH.

This instrument, introduced in 1867 by P. le Boulengé of Liège, is an improved form of an earlier chronograph invented by him in 1863. It was used for ascertaining the velocity of projectiles and for measuring very short intervals of time.

The instrument consists of a cylindrical column which supports two electro-magnets, from each of which a rod is held in suspension by the circuit.

The upper rod, known as the chronometer, is fitted with a removable zinc tube and is considerably longer than the lower one, which is known as the registrar.

In operation a projectile is fired through two wire screens placed, say, 120 feet apart. The first forms part of an electrical circuit which includes the upper electro-magnet, and the second screen is in another circuit including the lower electro-magnet. When the first circuit is broken the upper rod is released and falls vertically and, later, when the second circuit is broken the lower rod is similarly released, and falling on the end of a lever releases a circular knife edge which cuts into the zinc tube on the chronometer rod. A special rule is provided from which the velocity of the projectile corresponding with the distance between the knife-cut and a zero line on the tube may be obtained.

For the preliminary adjustments of the instrument arrangements are made whereby both rods are released at the same time. Inv. 1887–27.

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